News Feature: The neuroscience of poverty

Neuroscientists are investigating whether growing up poor shapes children's brains in ways that might also shape their lives.

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It wasn't the birth of her daughter that got cognitive neuroscientist Martha Farah interested in early brain development, but rather the babysitters she hired soon afterward. Most of these women were also mothers, single, and struggling to make ends meet with a combination of government benefits and cash from domestic work. Farah found herself getting closely involved in their lives: sharing meals, tutoring their children, lending money to their relatives. And she couldn't help but notice that as time went on, her child ended up on a different track from theirs.

"These kids started life with the same evident potential as my own daughter: loving their moms, learning words, playing games, asking questions," says Farah, who directs the Center for Neuroscience and Society at the University of Pennsylvania. "But somehow they found their ways onto a different kind of life trajectory: toward lower achievement and fewer options in life."

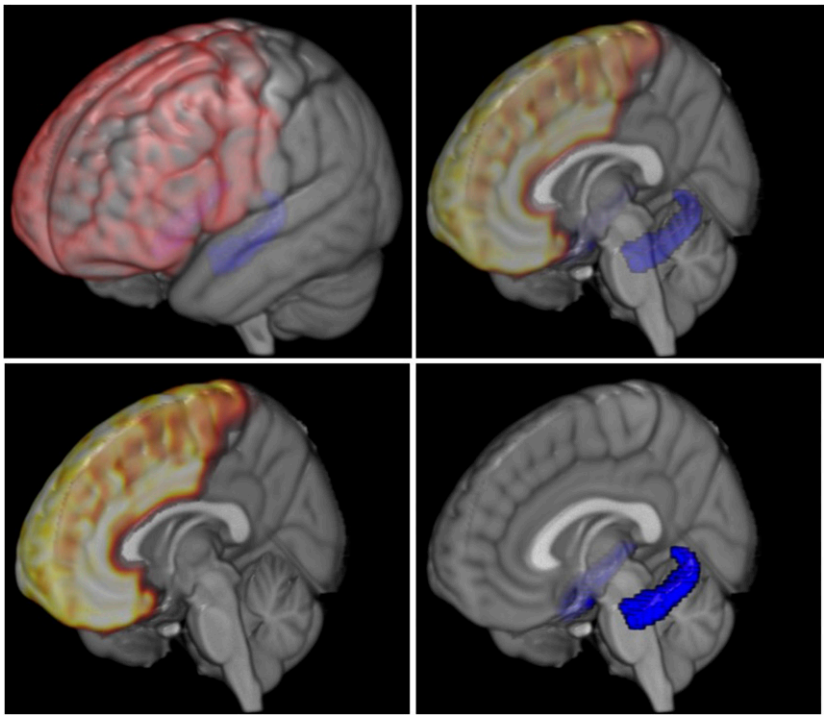
The observations ate at her, so she started to investigate. The literature revealed plenty of social science research showing a predictive link between children's socioeconomic status (SES) and lifelong health outcomes, academic achievement, and mental health. But nobody had ever made an explicit link to brain development. Farah began to wonder, could poverty be shaping these children's entire lives by shaping their brains in ways that diminish their chances of ever escaping poverty?

That was about 15 years ago, and from the start, sociologists, educational psychologists, and economists voiced enthusiasm about the idea of extending findings from the social science realm to the contours of the brain. Ironically, though, says Farah, her neuroscientist colleagues were, on the whole, less excited with her newfound research question. "I got grant reviews saying 'You're equating poverty with a brain disease,' or 'You're pathologizing poor children—this is irresponsible research,'" she recalls.

In the decade since Farah's team published their first paper on the topic (1), however, neuroscientists and cognitive psychologists have begun to dive into the fray. Half a dozen studies have correlated family SES with hippocampal volume in childhood; a handful have also pointed to differences in other brain structures and differences in the trajectory of brain growth. Recently, studies have started linking such brain differences to real-world outcomes like academic test scores. Even so, what these early data actually mean is still in question, and most agree the field is still in its infancy.

Concerns remain, too, about the broader significance of the research. If growing up in poverty leaves its mark on the brain in childhood, how reversible is it? What's the underlying cause? And, critics ask, if a social program has already been shown to alter the paths of poor families for the better, is the neuroscience really necessary to know that it works?

"I think we're onto something here; I do think that poverty is affecting children's brain development," says Seth Pollak, a professor of psychology at the University of Wisconsin, Madison. "But I think we have to be very cautious, particularly because this is an area of science that is right on the edge of being able to have some policy implications."



The major foci in the brain that appear to show disparities in poor children are the hippocampus and frontal lobe. These 3D renderings depict the hippocampus in blue and the frontal lobe in red/yellow. Image courtesy of Jamie Hanson (Duke University, Durham, NC, and the University of North Carolina at Chapel Hill, Chapel Hill, NC).

Visible Differences

The United States has some of the highest levels of childhood poverty outside the developing world, with one in five of all children—15 million in total—living below the federal poverty line of $24,250 for a family of four (2, 3). Economic deprivation isn't simply the absence of money, Farah says. For poor kids, it goes hand in hand with differences from other children in nutrition and prenatal

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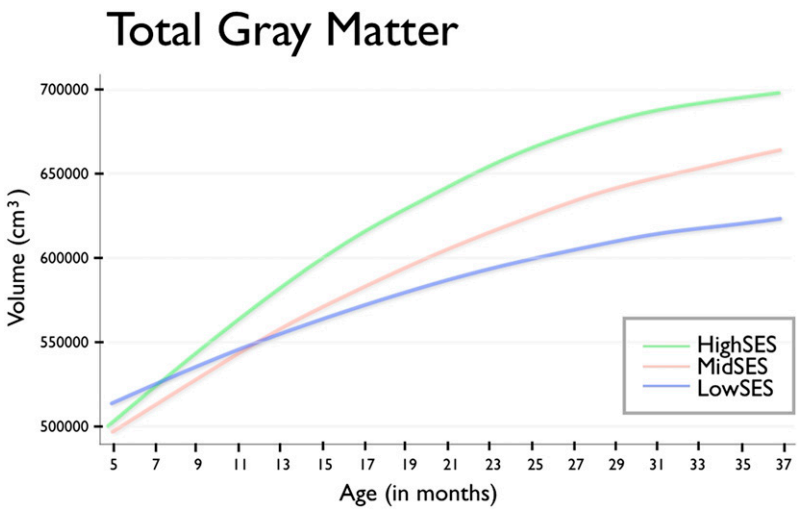

As age increases, household SES correlates with gray matter volume, according to work by Hanson et al. (11). Reproduced with permission from ref. 11.

care, parental education levels, neighborhood, and other environmental stressors. One of the most striking effects is the achievement gap: On the whole, children from poor families score lower on standardized tests, get worse grades, and attend college in much smaller numbers than those in middle class or affluent families. And this discrepancy is growing (4).

"By bringing in neuroscience you get a whole bunch of new potential explanations for the effects of poverty on the child," says Farah. For example, she says, poor children tend to have worse memories than their more affluent peers, in part because of higher levels of stress in poor families. Neuroscience reveals why: One design quirk of the brain is that the hippocampus, a key structure for consolidating memories, happens to be loaded with stress hormone receptors.

The early data revealed some intriguing disparities. Farah and her colleagues—including her then-graduate student Kimberly Noble, now a professor of neuroscience and education at Columbia University's Teachers College, and University of Pennsylvania neonatologist Hallam Hurt—found that SES didn't affect cognition across the board. Rather, deficits clustered in functions thought to engage specific brain circuits: for example, language, certain dimensions of memory, and the ability to regulate thoughts and emotions (1, 5).

Early-language expert Patricia Kuhl at the University of Washington used functional MRI to conclude that low-SES five-year-olds showed less specialization in a key region of the cortex implicated in reading (6). Helen Neville's group at the University of Oregon measured brain responses, called event-related potentials, to conclude that low-SES three- to eight-year-olds are slower to pay attention to a specified auditory input (7).

Much of the work over the past few years, though, has highlighted structural differences, including preliminary findings in the amygdala, which plays a role in processing fear and other emotions, and in the prefrontal cortex, involved in decision-making and self-control. The most consistent finding has been that of a smaller hippocampus in low-SES children.

The first study to report a hippocampal size difference came from Pollak's laboratory and relied on existing brain MRIs and family demographic data from a group of 317 children aged 4–18 years, drawn from a national United States developmental database (8). Two years later, Joan Luby and her colleagues at the University of Washington also found significantly smaller hippocampi in 145 poor 6- to 12-year-olds followed since preschool-age and compared with kids not living in poverty (9).

Luby's team hadn't even set out to explore how poverty changes the brain; they tracked it just to account for that variable in their study of depression and other psychiatric problems. But when they crunched the numbers, the signal was huge, Luby says. "Even though it wasn't our primary agenda, the data insisted that we follow up." The researchers also asked children and parents about stressful life events and assessed how encouraging and supportive their mothers were in a laboratory task. A statistical analysis found that the effects of poverty on the brain were stronger in children whose mothers were less nurturing or who experienced stress at home.

The largest analysis of brain structural differences across socioeconomic lines came this past March. Examining MRI scans of more than 1,000 subjects between the ages of 3 and 20 years from a national database, Noble et al. (10) detected smaller hippocampal volume in kids from families with less education (an oft-used proxy for SES). More significantly, they found differences in the surface area of the cerebral cortex. During childhood and adolescence, as myelin forms and neurons find their proper connections, cortical thickness decreases and surface area increases; past studies have associated the resulting surface area changes with intelligence. In Noble's study, on average, every additional year of parental education was associated with an increase of cortical surface area, specifically in parts of the cortex that handle language, reading, and self-regulation. The effect tracked with income as well, especially for the poorest families (10).

Complex Implications

One benefit of studying measurable changes in brain structure, says Farah, is that unlike functional imaging, it doesn't require foreknowledge of which cognitive processes might be affected. However, structural studies have their own challenges of interpretation. The hippocampal disparity, although robust across several studies in children, is not consistently seen in adults. Does that mean that kids' brains catch up? It's also unclear when exactly these differences emerge. Pollak and his colleagues compared the rate of overall brain growth in low-SES versus middle class kids and found that the trajectory starts to fall off for poor children in the toddler years, with a clear difference by the age of four (11). But in an ongoing longitudinal study of extremely poor children, Farah and her colleagues are finding differences in cortical gray matter volume within the first couple months of life, suggesting that some poverty-associated brain changes could be occurring prenatally.

Given the complexities of human brain development, not to mention the interplay of genes and environment during that process, it's still quite difficult to know what to make of the structural observations. Pollak and others also stress that these results are population averages, which smooth over a lot of variation. You can't look at an individual child from a low-SES background and glean much about her brain. Understanding the long-term environmental effects and whether or how kids' developing brains compensate for them will require more nuanced experiments that account for individual differences in children's response to poverty, says Silvia Bunge, a professor of psychology and neuroscience at the University of California, Berkeley. These could include protective cultural or personal traits that foster what psychologists term "resilience."

Slowly, the field is edging toward making more complex connections. Earlier this year, two published studies explicitly linked structural differences in the brains of children from disadvantaged families to their achievement. A small study of 58 adolescents by John Gabrieli's group at the Massachusetts Institute of Technology, published in April, was the first to relate cortical volume to scores on

state tests of math and reading (12). A paper published by Pollak and colleagues in July that analyzed MRI scans of 398 children and young adults between ages 4 and 22 reported that after adjustment for other factors, structural brain differences explained 20% of the testing gap between poor kids and middle class or well-off students (13). One value of tying brain measures to outcomes is that it opens the door for them to be used as biomarkers, or surrogate endpoints that could help determine whether an intervention is working, Gabrieli notes.

Still, not everyone agrees such markers are needed to describe either the problems of poverty or the solutions to it. "Getting a closer handle on how poverty influences neural development is a very interesting question," says Sandra Waxman, a professor of psychology at Northwestern University in Evanston, Illinois. "But even if the brain volume and the brain structure of the poor child looks identical [to that of the middle class child], there would still be reason for intervention." In other words, Waxman explains, if getting more pregnant low-income women to complete their GEDs has a positive effect on their children, then doing so shouldn't require additional neural measures of children's brains. There's also the question of messaging: framing the issue in terms of biological differences could errantly lead policymakers to assume that the effects are permanent, despite the fact that, especially in children, the brain is extremely plastic. "We have to be super-careful about this," says Bunge. "We don't want to entrench or reinforce any negative messages about poor people."

But proponents of the research say that the credence people put in biology is precisely why neuroscience should be invoked in the policy realm. "If you talk about something being a social justice issue, it doesn't always get people's attention," says Pollak. "But if you say, 'Look, this is affecting children's brains,' all of a sudden that changes the conversation." That change, he insists, is valid. "When you see things like this, you start thinking, 'Oh my gosh, this is a biomedical problem.' It is literally changing and retarding biological development. And the cost of that to our society is huge."

Capturing Cause and Effect

But what is it about poverty that changes brain structures? Is it prenatal and early childhood stress? Fewer opportunities for enrichment? Stressed parents and less nurturing home lives? Toxins like lead or pesticides? Poor nutrition? Of course, scientists can't test what it means for a rat or a monkey to be living from paycheck to paycheck, but animal studies have shown that many of these environmental factors associated with poverty can affect the brain. Stress and maternal nurturing, mediators suggested by the work of Luby and others, have particularly strong grounding in the animal literature (14).

To some extent, says Pollak, it's a question without an answer. "I think this *is* poverty," he explains. "Human brains are really resilient and versatile, and I think we can actually tolerate a whole lot without disrupting development. But I think what's happening in poverty is that all of these things happen together for long periods of time, and I think that's where these children's brains are taking a hit."

Whether the aim is to tease apart contributing mechanisms or just definitively link brain development and poverty as a whole, observational studies like the ones done to date are inadequate. The causality question can really only be addressed through experimental intervention, says Greg Duncan, a professor of education at the University of California, Irvine. Duncan spent the first 25 years of his career as a researcher on the government's Panel Study of Income Dynamics project, tracking economic, health, and social factors in thousands of families. Launched in 1968 and still running today, the project attempts to assess the outcome of President Lyndon Johnson's War on Poverty (15). That work led Duncan to seek out collaborations with developmental psychologists, and more recently with neuroscientists like Noble, to explore the links between family experiences of economic deprivation and behavioral and brain-related outcomes.

For the past few years, Duncan and Noble have been working to fund and launch a randomized controlled trial that would definitively answer whether income level causally contributes to kids' cognitive and brain development. The way the researchers envision it, low-income mothers of 1,000 babies born at four sites across the United States would receive debit cards for three years. Those randomly assigned to the treatment group would have their cards loaded with $333 per month, an amount that some studies suggest affects cognitive development in older kids (16) and is in the range of benefit levels in programs such as the Federal Earned Income Tax Credit for the working poor. Control group cards would have a nominal $20 per month. Families could spend the money any way they wished. On children's second birthdays, researchers would assess home environment, literacy activities, measures of family stress, and parents' mental health. At age three, kids would also receive a comprehensive battery of cognitive tests.

In an ongoing pilot trial with 30 New York City-area families, the team is testing a smaller monthly sum of $100 versus $20. "Some of us had thought that in New York City benefits are fairly generous and these payments won't mean a lot for people," says Duncan. "It's been rather sad to see how important even $20 is for a family."

Unrestricted cash payments as a cognitive treatment make a lot of psychologists nervous. "Based on prior cash transfer studies, it doesn't seem that it always works out that the money gets spent the way you hope it'd get spent," says Bunge. "I'm much more excited about programs that try to help people figure out obstacles that get in the way of having a job, finding childcare, getting them on their feet."

But Noble believes the study's scientific potency will stem from the families' ability to use the money as they see fit. If poverty is the common mediator diminishing cognitive power, cash may be the most widely effective treatment. "It's very possible that the mechanism by which poverty operates will be different for each family," she says, "whether it allows parents to buy more books for their kids, work fewer jobs to be around their kids more, or just reduces the stress for a parent about how they're going to pay the rent."

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