



BEHAVIORAL NEUROSCIENCE

Brain Trust

POVERTY AFFECTS THE SIZE, SHAPE AND FUNCTIONING OF A YOUNG CHILD'S BRAIN. WOULD A CASH STIPEND TO PARENTS HELP PREVENT HARM?

By Kimberly G. Noble



Illustration by Peter Horvath

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ROWING UP POOR DOES MORE THAN DEPRIVE A BILLION children and adolescents worldwide of basic material necessities. Poverty places the young child's brain at much greater risk of not going through the paces of normal development to eventually become the three-pound wonder able to perform intellectual feats, whether composing symphonies or solving differential equations.

Children who live in poverty tend to perform worse than their more advantaged peers on IQ, reading and other tests. They are less likely to graduate high school, less apt to go on to college and receive a degree, and more prone to be poor and underemployed as adults. These correlations are not new, and brain development is only one contributing factor among many. Until the past decade, however, we had only the vaguest idea of what impact poverty actually has on the developing brain.

My laboratory, along with a few others, has begun to explore the relation between a family's socioeconomic status (SES)—a measure that gauges income, educational attainment and occupational prestige—and children's brain health. We have found that socioeconomic disadvantage is associated with tremendous differences in the size, shape and actual functioning of children's brains.

The recognition of poverty's potential to hijack normal brain development has led us to propose a simple remedy to alleviate the hardships of being poor. We are planning a study to gauge the effect on a young child's health of giving a cash stipend to families to help ease their financial straits. The study is the first to probe whether a modest elevation in income could help build a better brain. If it succeeds, it could provide a clear path that proceeds directly from basic brain science to the formulation of new public policy.

LOOKING FOR ANSWERS

WHEN I BEGAN THIS RESEARCH 15 years ago, I was a graduate student at the University of Pennsylvania. At the time, my adviser, Martha Farah, wanted to know more about how poverty affected early brain development. Luckily for me, she asked me to be her first student to tackle this challenge.

The project required careful deliberation about what research methods we would use. The splashiest techniques involved brain imaging, in which powerful machines take pictures that are analyzed to reveal structure (how the brain looks) as well as function (how the brain operates). As enticing as brain imaging is, it is also expensive: a single scan typically costs hundreds of dollars, which does not include compensation to study participants or research assistants who analyze the data.

Because we were taking on a research question that had not been addressed before, we decided to look for techniques that were simple and inexpensive and would allow us to recruit as many study participants as possible. The search led us to a straightforward solution: the use of standard methods to measure cognition. Unlike previous studies that looked at the effects of poverty, we decided not to rely on broad indices of achievement, such as high school graduation rate. This is because no one part of the brain is responsible for graduating from high school. Rather different brain circuits are involved in processing distinct cognitive skills, many of which are important for academic and life achievement. For instance, we know that when people have strokes or develop lesions in a region of the left side of the brain known as Wernicke's area, they have difficulty understanding language. We have also found, from neuroimaging studies, that healthy individuals use this same area when they listen to speech. From this work, scientists have deduced that healthy individuals use this region whenever they participate in a task that involves listening to and understanding speech. We do not need to take a picture each time to know that is so.

In this way, we decided to use well-established psychological testing methods to assess children's language capabilities with-

IN BRIEF

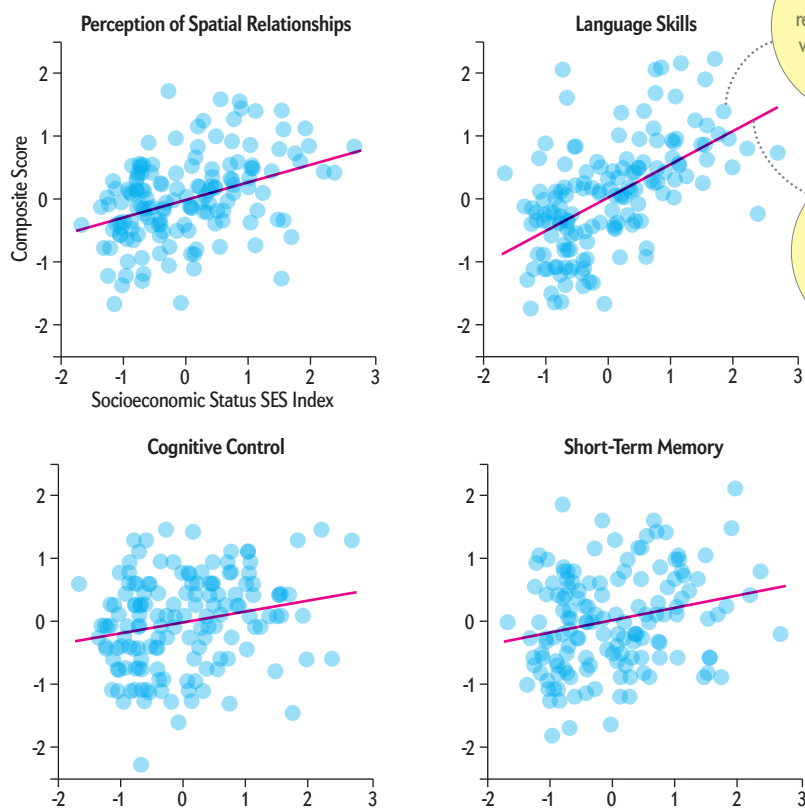
Children who live in poverty tend to perform worse than peers in school on a bevy of different tests. They are less likely to graduate from high school and then continue on to college and are more apt to be underemployed once they enter the workforce.

Research that crosses neuroscience with sociology has begun to show that educational and occupational disadvantages that result from growing up poor can lead to significant differences in the size, shape and functioning of children's brains.

Poverty's potential to hijack normal brain development has led to plans for studying whether a simple intervention might reverse these injurious effects. A study now in the planning stages will explore if a modest subsidy can enhance brain health.

Wealth Effect

Children tended to perform better on various cognitive skills when socioeconomic status (SES) was higher. SES was the factor that explained nearly a third of the difference in performance on language tasks between children from high- and low-income homes, whereas it demonstrated a smaller but still significant portion for other cognitive measures.



out having to scan their brain. The question posed was: How do socioeconomic disparities relate to brain function?

In conducting our study, we recruited several groups of families from varied socioeconomic backgrounds whose children ranged in age from kindergarten through adolescence. We then administered to the children cognitive tests that served as a measure of the integrity of different brain circuits. Our results were remarkably consistent across multiple studies. In general, children from more disadvantaged homes tended to perform more poorly on tasks that tested their language and memory skills and the ability to exert self-control and avoid distraction.

In some cases, we and other groups carrying out similar research did need access to more advanced imaging tools to determine if family SES relates to differences in the size and shape of key brain areas involved in higher cognitive processes. Four independent research groups have now reported that children whose parents earn higher incomes tend to have a larger hippocampus, a structure located deep in the brain that is critical for memory formation. Other work has focused on the size and shape of the cerebral cortex, the wrinkled outer layer of brain cells that does most of the cognitive “heavy lifting.” Several early studies have examined whether SES correlates with the volume of the cortex.

To understand what is meant by volume, picture the cortex as if it were shaped roughly like a can of soup. We can calculate the amount, or volume, of soup that the can holds by multiplying the height of the can—known in brain parlance as the cortical thickness—by the area of the circle on top of the can, which is analogous to the cortical surface area.

Measurements of cortical volume must be done with care. It is easy to be misled because the same cortical volume can exist with a large surface area and a small cortical thickness or with a substantial thickness and a tiny surface. Cortical thickness tends to decrease with age—our hypothetical soup can shrink down to the size of a tuna fish can—but our cortical surface area tends to increase with age. It is as if we started out with a small can of tomato paste, which grows wider over time to the width of a full-fledged can of soup.

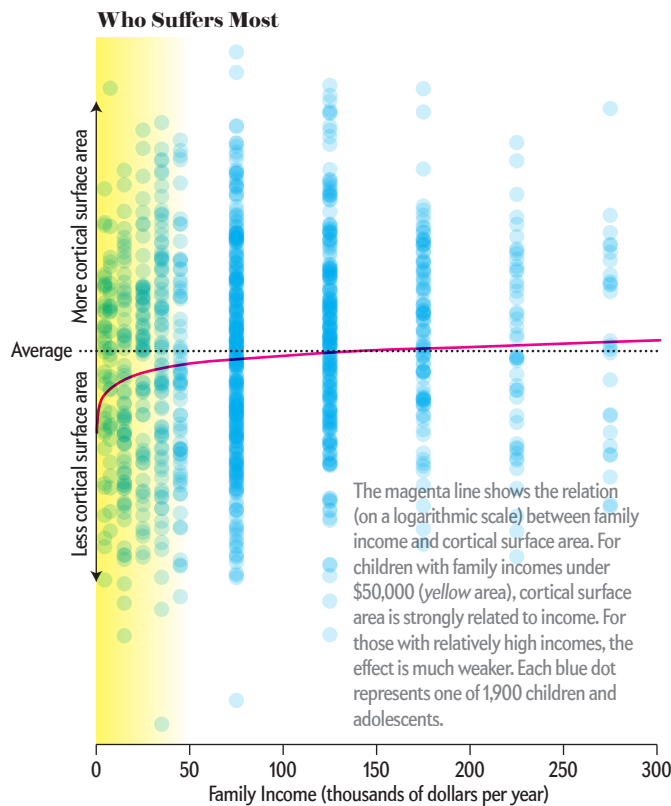
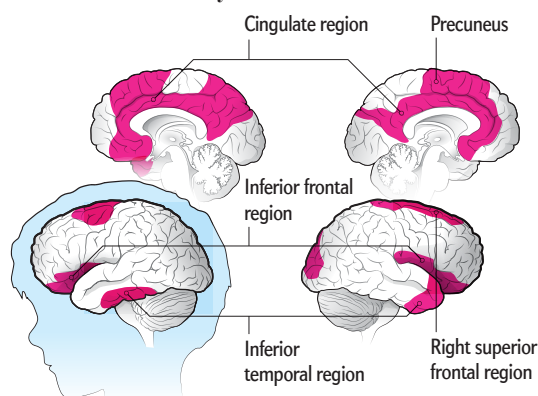
With our set of software-measuring tools in hand, we recently looked at whether socioeconomic disparities affect both cortical surface area and thickness. In the largest study of its kind to date, published in 2015 in *Nature Neuroscience*, we analyzed the brain structure of 1,099 children and adolescents, recruited from socioeconomically diverse homes from 10 sites across the U.S. We found that both parental educational attainment and family income were associated with differences in the surface area of the cerebral cortex. Children from families that earned less than \$25,000 a year had 6 percent less cortical surface area than those from families that earned more than \$150,000. These associations were found across much of the brain but were particularly pronounced in areas that process language and govern impulse control and other forms of self-regulation—abilities that have repeatedly shown substantial differences across socioeconomic lines.

For this study, we took into account several key variables. First, as a proxy for race, we controlled for the proportion of genetic background each individual had from six major populations (African, Central Asian, East Asian, European, Native Am-

A Brain on Poverty

The travails of an impoverished upbringing reduce the surface area of some parts of the cortex more than others. The affected regions (*pink*) participate in various forms of mental processing. The researchers demonstrated the connection by plotting collected measures of the affected regions (referred to as the cortical surface area) by socioeconomic status.

Areas of Vulnerability



erican and Oceanic). We determined from the data that socioeconomic disparities that we observed in brain structure were independent of genetically defined race.

We saw dramatic differences from person to person. For example, some children and adolescents from disadvantaged homes had larger cortical surface areas, whereas some advantaged children had smaller areas. We might consider a comparable situation with gender and height: in childhood, boys tend to be taller than girls, but we know that in every elementary school classroom, some girls are taller than some boys. Along the same lines, although children from higher-income homes tended to have larger brain surfaces, our research team could not predict an individual's brain size simply only by knowing his or her family income.

The relation between family income and surface area was strongest at the lowest end of the income spectrum and tended to level off at higher-income brackets. That is, dollar for dollar, differences in family income were associated with proportionately greater differences in brain structure among the most disadvantaged families.

In another recent study, we reported on socioeconomic disparities in cortical thickness. Overall, cortical thickness tends to decrease with age. But our work suggests that a family's socioeconomic circumstance may influence this trajectory. At the lower levels of family SES, cortical thickness tended to decrease steeply earlier in childhood, leveling off during adolescence. At higher SES levels, cortical thickness declined more gradually with age through late adolescence.

This finding is consistent with work from other labs suggest-

ing that adversity can, in some cases, accelerate brain maturation—in essence, causing a young child's brain to “grow up” more quickly. The rapid reduction of cortical thickness suggests that many poor children's brains may lack “plasticity”: an ability to change in structure to accommodate the essential learning that takes place during childhood and adolescence.

Of course, one of the most important questions we needed to answer was whether differences in brain structure affected a child's cognitive abilities. The disparities we found in brain surface area seemed to confirm, in part, previous findings that higher family income predicts a child's ability to pay attention and inhibit inappropriate responses. Work by Seth Pollak of the University of Wisconsin–Madison and separate studies by John Gabrieli of the Massachusetts Institute of Technology have suggested that differences in brain structure (cortical volume or thickness) may account for between 15 and 44 percent of the gap in educational achievement for an adolescent from a low-income household.

This line of research is compelling but still in its infancy. We still need to learn what causes the association between SES and brain development. Is it differences in nutrition, neighborhood, school quality, parenting style or family stress, or a combination? Are we even certain that all these differences are explained by experience—or do genetics also most likely play a role?

Few studies to date have directly examined these questions. A recent finding by Joan Luby and her colleagues at Washington University in St. Louis provides some evidence that income disparities in children's brain structure may be accounted for by stressful life events and differences in parenting style. Less supportive and

more hostile parenting appears to lead to worse outcomes—in this case, a smaller hippocampus. In my lab, we are looking at how chronic stress and the absence of verbal interaction between parents and children may, in part, explain these findings.

Another persistent question was whether the difficulties experienced early in life by poor children stem more from their time in the womb than with family income after they are born. Our group reported recently that brain function in the first four days of life bore no relation to parents' income level or educational attainment, lending support to the idea that socioeconomic disparities in brain development result from differences in postnatal experience. This work still needs to be replicated, given that the sample used in that study was relatively small: only 66 families. But work by several other research groups has suggested that some structural or functional brain differences may become evident only later in the first year of life.

We do not yet have the evidence to explain the links between family, social and economic circumstances and a child's growing brain. Disentangling the connections among SES, early childhood experience and brain development will remain a clear priority for future research.

CORRELATION IS NOT CAUSATION

ALTHOUGH DOZENS OF STUDIES have supplied evidence of the relation between family income and healthy brain development, this type of research needs to be placed on a surer footing. The oft-cited adage "correlation is not causation" helps to explain the lingering uncertainty: Does growing up in a disadvantaged home cause differences in the brain, or does a distinct developmental course lead a child to flounder in school or at work?

The field of neuroscience has been silent on the issue of causality. To test cause and effect, we need the gold standard of scientific testing: a randomized controlled trial in which one "treatment" group is assigned randomly to receive an intervention, and the other is randomized to receive the "control" experience, enabling us to assess the impact of one intervention or another on brain development.

For this type of study, a research team needs to assess, for instance, what should be the right intervention to reduce socioeconomic disparities. Quite a few school and home-based interventions, such as Head Start, already aim to reduce divergences in children's achievement. Indeed, many of these efforts are effective, even though the challenges such interventions face are often daunting: high-quality interventions are expensive, difficult to scale up and often suffer from "fade-out," in which positive effects dwindle with time once children are no longer receiving services.

Given these difficulties, we have decided to consider a much simpler intervention—one that is easy to administer and would in principle have near-perfect acceptance in the community. The study we have designed will consider the effects on brain development of directly supplementing family income with a monetary subsidy. Cash transfers, as opposed to counseling, child care and other services, have the potential to empower families to make the financial decisions they deem best for themselves and their children. Evidence from studies conducted both in the U.S. and in the developing world has suggested that direct income supplements may hold promise. The idea of supplying a universal basic income is gaining traction and is

being piloted by several charitable organizations and governments around the world.

But none of these studies so far has measured the effects of family income supplementation on children's brain development. Recently we have formed a team of experts from the social sciences and neurosciences to pursue this question. I am working with economist Greg Duncan of the University of California, Irvine, developmental psychologists Katherine Magnuson of the University of Wisconsin–Madison and Hirokazu Yoshikawa of New York University, and economist Lisa Gennetian of N.Y.U. We are raising funds to launch the first ever randomized experiment to test a cause-and-effect connection between poverty reduction and brain development. The goal of this study is ambitious, although the premise is straightforward. We will begin by recruiting 1,000 low-income U.S. mothers at the time of a child's birth, and mothers will be randomized to receive a \$333 monthly income supplement or a \$20 monthly income supplement.

Funds will be disbursed on a preloaded debit card to the mothers who sign up for the study in the hospital where a child is born. The debit card will be automatically reloaded each month for the duration of the study. No constraints will be placed on how the money is spent. Families will be tracked over the first three years of the children's lives to gauge the impact of the unconditional cash transfer on cognitive and brain development.

We will also carefully measure numerous aspects of the families' lives, including stress, the quality of family relationships and how recipients use the funds provided. A recent one-year pilot study involving 30 low-income mothers suggested that our approach is quite feasible and that a debit card can serve as a reliable means for distributing income to mothers. Although a substantial number of participants had never previously used a debit card, they reported few problems with card activation, accessing cash or using it for point-of-sale transactions. This gives us confidence that our approach could scale up to the level of a full study.

Our hypothesis is that increased family income will trigger a cascade of positive effects for these families. As their children pass through early childhood, we posit that they will be better able to develop visual, auditory and other critical cognitive skills at the pace of children from families at higher-income levels.

If our hypotheses are correct, our trial has the potential to inform social policies that affect the lives of millions of disadvantaged families with young children. We suspect that such policies could be put in place with an uncomplicated government infrastructure. Although income may not be the only factor that determines a child's developmental trajectory, it may be the easiest one to alter from the standpoint of implementing policy—a down payment of sorts to promote the health of a growing child's brain. ■

MORE TO EXPLORE

Socioeconomic Gradients Predict Individual Differences in Neurocognitive Abilities. Kimberly G. Noble et al. in *Developmental Science*, Vol. 10, No. 4, pages 464–480; July 2007.

Family Income, Parental Education and Brain Structure in Children and Adolescents. Kimberly G. Noble et al. in *Nature Neuroscience*, Vol. 18, pages 773–778; May 2015.

FROM OUR ARCHIVES

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