Poverty reduction and the developing brain

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A growing body of small-scale studies documents that the cognitive functioning of low-income children differs from that of children born into higher-income families. Differences favoring more affluent children have been shown for diverse behavioral measures of language, memory, executive function, and socioemotional processing, with corresponding differences in neural structure and function in brain regions that support these skills.[1] At the same time, a large body of social science research documents income disparities in more general measures of children's achievement, school performance, and learning related behaviors such as attention and self-regulation.

Across disciplines, developmental scientists agree that poverty is especially likely to shape children's early development because of the high plasticity and rapid growth of neurobiological development during the first three years of life. Policy makers and the public often assume that associations between family income and cognitive functioning represent *causal* connections and that boosting the incomes of poor children would improve cognitive functioning and success in school and beyond. Given the correlational nature of virtually all of this neuroscience research, scientists' warnings that correlation does not prove causation mean that drawing solid policy implications is premature.

We propose the first ever randomized experiment testing causal connections between poverty reduction and brain development. We plan to randomly assign some 1,000 low-income mothers and their newborns in seven ethnically and geographically diverse communities to either (1) an experimental group that receives $4,000 in cash payments each year for each of the first three years of the children's lives, with the first payments occurring shortly after the baby's birth, or (2) a control group that receives much smaller payments ($240 per year). Recent research suggests that the $3,760 difference may well be large enough to produce detectable differences in children's cognitive development. We will also test variations in the frequency of payments to low-income families, a critical policy dimension in U.S. income support policy with important consequences for families' economic stability.

To understand how poverty reduction improves brain functioning we will measure family expenditures and time use, parent stress and parenting practices, and a host of other measures of everyday family life at child ages one and two. Rigorous lab-based measures of child cognitive functioning, health and behavior will be gathered at age three.

Results would provide definitive evidence about the magnitude and pathways of causal connections between poverty reduction and early cognitive development. Beyond its core contributions to both neuro- and social science research, the proposed project will provide a solid scientific foundation for a variety of tax and income-enhancement policies, including the Child Tax Credit and Earned Income Tax Credit, employment-related programs, and the full range of U.S. social policies related to family economic well-being.

SOME DETAILS:

Who we are:

Neuroscientists: Kimberly Noble, MD, PhD, *Columbia University*; Nathan Fox, PhD, *University of Maryland*; Charles Nelson, PhD, *Harvard University.*

Social scientists: Katherine Magnuson, PhD, *University of Wisconsin, Madison*; Greg J. Duncan, PhD, *UC Irvine*; Lisa Gennetian, PhD, *National Bureau of Economic Research;* Hirokazu Yoshikawa, PhD, *Harvard University*.

Collectively, our expertise spans neuroscience, economics, and developmental psychology. Four of us hold chaired and/or distinguished professorships at leading research universities. All but one of us has extensive experience with experimental studies (e.g., the Bucharest Early Adoption Study; Moving to Opportunity; the welfare-to-work experiments conducted by MDRC in the 1990s; the *Un Buen Comienzo* preschool experiment in Chile; the national Head Start Impact Study). Several of us have directed large longitudinal data collection projects (e.g., the Panel Study of Income Dynamics). Several of us have written widely-cited studies of the neuroscience (Noble) and social science (Duncan and Magnuson) linkages between poverty and child development. All of us have collaborated closely with one or more of the rest on major research projects.

What we would do:

Some 1,000 infants born to mothers with low socioeconomic status (income at eligibility levels for Medicaid or roughly below 180% of the poverty line) in seven sites across the United States will be assigned at random to experimental or control groups. Experimental group parents would receive cash payments of $4,000 per year for three years, with the form of payment structured according to behavioral economic principles to be maximally beneficial for meeting the economic needs of low-income families. The comparison group would receive a nominal payment -- $240 per year, delivered in the same ways. To address ethical concerns regarding coercion, neither of these payments would be conditioned on participation in the study beyond the initial hospital-based consent. Following standard research procedures, all participating families would receive a $100 respondent incentive for participating in three of our four planned interviews and a $200 payment for our proposed age-3 laboratory assessments. We take into account likely 20% attrition over the course of the 3 years of the study. Sites include:

New York-Presbyterian Hospital, Columbia University Medical Center, New York	South Carolina Medical Center, Columbia, South Carolina
Boston Children's Hospital, Boston	X, Milwaukee
X, Maryland	UC Irvine Medical Center, Orange, CA
Tulane Medical Center, New Orleans	

Mothers will be recruited in maternity wards of participating hospitals shortly after giving birth and, after consenting, will be administered a 20-minute baseline interview. We will collect information from the mother on the phone when the infant is 12 months old and in the home from the mother and child at the children's second birthday. At age 3, mothers and children will be assessed and interviewed in research labs at each site.

The three yearly visits – and especially the lab visit at age 3 – will provide a host of developmentally appropriate measures of children's cognitive and behavioral functioning. Questions asked of the mothers and interviewer observations will measure a variety of the family pathways (e.g., maternal stress and mental health, time spent with child; quality and cost of child care and other child-related expenses) that are hypothesized to explain the poverty-brain connections. Follow-up studies beyond the children's third birthdays will be undertaken contingent on results from our proposed three-year data collection period.

The compensation difference between families in the experimental and control groups would boost family incomes by $3,760 per year, an amount shown in economics and developmental psychology to be associated with socially significant and policy relevant improvements in children's school achievement. After accounting for likely attrition, our total sample size of 800 at age 3 years, evenly divided between experimental and control groups, provides ample statistical power to detect meaningful (.20 sd – the equivalent of 3 IQ points) differences in cognitive functioning, and key dimensions of family context.

Cognitive measures at age 3

Investigations of socioeconomic disparities in children's achievement in the social sciences have typically assessed important childhood cognitive and academic benchmarks such as IQ, reading and math achievement, grade retention and school graduation rates. Such measures tell us in broad strokes that increases in income among children from poor families should lead to increases in academic achievement. However, these measures tell us little about the mechanisms that affect the development of distinct cognitive and neural processes, impeding our efforts to design targeted preventive strategies and remedial interventions. By taking a cognitive neuroscience approach – based on the principle that different neural structures and circuits support different types of cognitive skills – we can investigate how poverty operates through more proximate factors to shape the development of specific cognitive and neural systems.

For example, income disparities in early childhood have been repeatedly associated with large differences in language development, with more modest but consistent associations reported between income and measures of childhood memory, executive functioning and socioemotional processing. Each of these cognitive domains is supported by a distinct brain system. An income boost may, to varying degrees, result in improved performance of these domains of children's cognition and behavior. To test this, at the age-three lab visit we will administer behavioral tasks selected from NIH Toolbox, which comprises a set of validated, reliable, and developmentally sensitive measures which have been normed from age three through adulthood. By examining how these relatively precise measures of child development are differentially affected by poverty reduction, we pave the way for educational interventions that target the specific cognitive outcomes most affected by poverty.

To date, direct studies of the effects of poverty on brain development are scarce, let alone studies of the effects of poverty *reduction*. However, recent studies by our team and others have reported correlations between poverty and brain structure/function in several neural regions that support language, memory, executive function and socioemotional skills, respectively.[2], [3] Electrophysiological measures are particularly useful in assessing neural processing in early childhood. Resting electroencephalography (EEG) is commonly quantified using *power*, an index of brain activity *within* a neural region, and *coherence*, a measure reflecting synchronization *between* neural regions.

Our team and others have shown that, in certain parts of the brain, different types of power and coherence are correlated with better cognitive and verbal abilities in young children. We hypothesize that poverty reduction will lead to increases in these types of power and coherence in these brain regions, and that these EEG variables will mediate the link between income and language ability.

Similarly, our team and others have shown that, across the whole brain, children reared in adverse conditions have an excess of one type of EEG power ("slow wave") and a deficit in a different type of power ("high frequency"). Importantly, reducing adversity through, for example, early adoption out of an orphanage) can partially normalize these patterns. We therefore hypothesize that poverty reduction will lead to lower levels of slow wave EEG power and an increase in higher frequency EEG power. Early adversity has particularly important effects on the neural circuits that support memory, executive function and socioemotional processing, and thus we hypothesize that these EEG variables will partially mediate the links between income and these cognitive skills.

Family processes that facilitate brain development

If poverty reduction shapes early brain development and cognitive functioning, it is important to discover *why*. Social scientists have posited two complementary pathways by which low family incomes shape the context of child rearing. First, additional resources enable parents to buy goods and services for their families and children that support cognitive development. These include higher quality housing, nutrition and non-parental child care; more cognitively stimulating home environments and learning opportunities outside of the home; and, by reducing or restructuring work hours, more parental time spent with children. These boosts in children's experience of enriching environments may improve their cognitive functioning, in particular language skills and IQ, by increasing the connectivity and coherence of brain neural networks. Measurement of these features of the child's environment will be collected during the in-home interview when the child is 2 years old.

A second pathway is that additional economic resources may reduce parents' own stress and improve their mental health. This in turn may allow parents to devote more positive attention to their children, thus providing a more predictable family life, less conflicted relationships, and warmer and more responsive interactions. Research suggests that warm and responsive caregivers are able to help children regulate their stress responses, thereby reducing the likelihood that children experience the kind of prolonged activation of their stress response systems that has been linked to compromised neural development in the areas of the brain that affect memory, executive functioning, and socioemotional processing. All in all, understanding, pathways by which poverty affects families and children will further our ability to intervene successfully to support the healthy development of vulnerable children. Measurement of maternal stress and mental health will collected at ages 1 and 2.

Mode of cash payments: Insights from behavioral economics

In addition to the neuroscientific and social data we will gain from this study, we aim to inform national poverty reduction policy. For example, most existing income-based policies in the U.S implicitly assume that parents are highly competent budgeters and savers and thus able to allocate their incomes to meet current needs and take steps in anticipation of future changes in income and expenses. In reality, many poor families are not only cash-constrained, but also face erratic income flows, save little and lack access to low-cost sources of credit. As a result, when

faced with income gaps or shortfall, low-income families are often forced to cut back on expenditures, even for essential goods such as food and housing.

Recent research in behavioral economics and psychology has shown that such periods of economic hardship can constrain parents' judgment and redirect attention toward coping with the financial crisis at hand, potentially at the cost of neglecting children's needs for nurturing interactions.[4] We will test these behavioral economic principles by altering the timing and frequency of the cash payment in ways that increase cash flow to families at moments when income is predicted to be the most constrained. For example, our prior work shows that the end of the month, when income from government assistance may be depleted and the next payment is not expected until the beginning of the next month, can increase children's school disciplinary problems.[5] More frequent predictable payments is predicted to reduce parental attention needed to actively budget and thus free up that attention towards positive interactions with their children. Specifically, some experimental-group families will receive more frequent payments (monthly) and others will receive lump sum payments at the time of the child's birthday. Data from this comparison will inform the payment structure of the Earned Income Tax Credit and other U.S. policies for the poor.

Timeline and budget

We propose a five-year plan of work, with the first six months devoted to finalizing the design of instruments and sample recruitment. The 1,000 mother and infants will be recruited between months 7 and 18 of the project period. Between months 19 and 31, recruited infants would be celebrating their first birthdays, with accompanying telephone interviews with their mothers. In-home interviews timed to children's second birthdays will take place over months 32 to 43 of the project. Third-birthday lab visits would take place between months 44 and 55. Key impact analyses would begin with partial data from the lab assessments during months 49 to 55 and be completed by the end of the 60th month.

The data we collect will support a great deal of additional analysis. We anticipate writing proposals to support these efforts in the years beyond our current project period. We are also interested in the public good that may result from this project – accordingly, we plan to issue a public-use data file 12 to 15 months following the completion of our third-birthday laboratory-based data collection. We are eager to generate additional funding for continuing to follow the sample beyond the children's third birthdays, providing that the impact data we collect show meaningful impacts on child and family functioning.

We are still working out the budget details for our costly project. Respondent payments alone will approach $7 million if we are able to maintain contact with all of our respondents. Direct costs for the survey work sum to roughly $3.5 million. We estimate that the direct costs of lab visits, time of PIs and staff, travel and other project-related expenses will sum to roughly $3 million over the course of the five project years.

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[1] Duncan G and Magnuson K, (2012) "Socioeconomic Status and Cognitive Functioning: Moving from Correlation to Causation" *Wiley Interdisciplinary Reviews: Cognitive Science,* 3:377–386.

[2] Noble, K. G., et al. (2012). "Neural correlates of socioeconomic status in the developing human brain." *Developmental Science* **15**(4): 516-527; Stevens, C., et al. (2009). "Differences in the

neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study." *Developmental Science* **12**(4): 634-646., Hanson, J. L., et al. (2011). "Association between Income and the Hippocampus." *PLoS ONE* **6**(5): e18712., Jednoróg, K., et al. (2012). "The influence of socioeconomic status on children's brain structure." *PLoS ONE* **7**(8): e42486..

[3] We acknowledge that structural or functional magnetic resonance imaging (s/fMRI) has far greater spatial resolution than EEG. However, EEG measures are particularly well suited to studying neural processes in toddlers, as, unlike MRI, they do not require the young child to sit perfectly still in a dark and noisy tube, but rather, allow for the child to sit comfortably on the parent's lap. Further, the far greater expense of MRI compared to EEG would render the former unfeasible in the current proposal. If the poverty reduction intervention proposed here suggests meaningful impacts on child development, a natural future follow-up study will include assessing MRI on a subset of participants as children get older.

[4] Shah, A., S. Mullainathan and E. Shafir (2012). Some Consequences of Having Too Little. Science. 338: 682-85; Gennetian, L., S. Mullainathan and E. Shafir (2012). The Persistence of Poverty in the Context of Economic Instability: A Behavioral Perspective. Working Paper

[5] Gennetian, L., R. Seshadri, N. Hess, A. Winn, and R. Goerge (2012) Running Out and Acting Out: Food Stamp Benefit Cycles and School Disciplinary Events Among Chicago Public School Students.