What do we know about the effects of poor neighborhoods on children’s neurological development and lifelong health?

Nathan Fox
Distinguished University Professor
University of Maryland
MEMBER, NATIONAL SCIENTIFIC COUNCIL ON THE DEVELOPING CHILD

AFTER THOMPSON: Getting Kids Out of Harm’s Way - Implications for the Wellbeing of Children
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Three Core Concepts of Development

1. Brain Architecture Is Established Early in Life and Supports Lifelong Learning, Behavior, and Health

2. Stable, Caring Relationships and “Serve and Return” Interaction Shape Brain Architecture

3. Toxic Stress in the Early Years of Life Can Derail Healthy Development
Experiences Build Brain Architecture
Brains are built over time, starting in the earliest years of life. Simple skills come first; more complex skills build on top of them.

Cognitive, emotional, and social capabilities are inextricably intertwined throughout the life course.

A strong foundation in the early years improves the odds for positive outcomes and a weak foundation increases the odds of later difficulties.
The Ability to Change Brains Decreases Over Time

Normal Brain Plasticity
Influenced by Experience

Physiological “Effort”
Required to Enhance Neural Connections

Source: Levitt (2009)
Neural Circuits are Wired in a Bottom-Up Sequence

Sensory Pathways (Vision, Hearing)

Language

Higher Cognitive Function

FIRST YEAR

Birth (Months) (Years)

Critical Period

time during development when a reversal of architectural change, caused by a manipulation, can occur; the period ends when reversal is no longer possible

Sensitive Period

the time during development when a specific manipulation changes the brain structure

Window of opportunity
A) Non-selective to Highly selective

B) Initial to Learned

Experience
Early Experience Changes Brain Architecture – The Tale of Two Environments
Experience Shapes Brain Architecture by Over-Production Followed by Pruning

(700 synapses formed per second in the early years)
Interaction Shapes Brain Circuitry
Serve & Return Builds Brains and Skills

Young children naturally reach out for interaction through babbling, facial expressions, and gestures, and adults respond in kind.

These “serve and return" interactions are essential for the development of healthy brain circuits.

Therefore, systems that support the quality of relationships in early care settings, communities, and homes also support the development of sturdy brain architecture.
How Early Experiences Alter Gene Expression and Shape Development
Genes Carry Instructions that Tell Our Bodies How to Work
Early Experiences Leave Lasting Chemical “Signatures” on Genes

External Experience

Gene Regulatory Proteins

Epigenetic “Signature” Turns Gene On or Off
Barriers to Educational Achievement Emerge at a Very Young Age

- College Educated Parents
- Working Class Parents
- Welfare Parents

PAPER

SES differences in language processing skill and vocabulary are evident at 18 months

Anne Fernald, Virginia A. Marchman and Adriana Weisleder

Department of Psychology, Stanford University, USA
Figure 1  Scatter plots of Vocabulary, Accuracy and RT at 18 months with SES (HI). Dashed vertical line indicates median split of HI values.
Toxic Stress Derails Healthy Development
The Biology of Adversity: Three Levels of Stress

Positive
Brief increases in heart rate, mild elevations in stress hormone levels.

Tolerable
Serious, temporary stress responses, buffered by supportive relationships.

Toxic
Prolonged activation of stress response systems in the absence of protective relationships.
Learning how to cope with moderate, short-lived stress can build a healthy stress response system.

Toxic stress—when the body’s stress response system is activated excessively—can weaken developing brain architecture.

Without caring adults to buffer children, toxic stress associated with extreme poverty, neglect, abuse, or severe maternal depression can have long-term consequences for learning, behavior, and both physical and mental health.
Persistent Stress Changes Brain Architecture

Normal

Chronic stress

Prefrontal Cortex and Hippocampus

Bock et al Cer Cort 15:802 (2005)
Sources of Toxic Stress in Young Children

U.S. Children Ages 2-5 (per 1,000)

- Maltreatment: 75
  - Source: Finkelhor et al. (2005)
- Postpartum Depression: 130
  - Source: O-Hara & Swain (1996)
- Parental Substance Abuse: 136
  - Source: SAMHSA (2009)
Poor Children Experience Elevated Stress

Overnight levels in rural 9-year-old white children

New Biological Evidence Links Maltreatment in Childhood to Greater Risk of Adult Heart Disease

Source: Danese et al. (2008)
Chronic Diseases Associated With Childhood Adversity Dominate U.S. Health Care Costs

Five of Top Ten Diagnoses for Direct Health Expenditures = $335 billion

Source: Agency for Healthcare Research and Quality (2008)
The Childhood Roots of Health Disparities: How Adversity is Built Into the Body

Conception

Early Adversity
- Toxic Stress
- Environmental Exposures
- Malnutrition

Physiological Disruption
- Neurodevelopmental
  - Immune
  - Metabolic
  - Neuroendocrine
  - Cardiovascular

Cumulative Burden over Time

Middle Childhood

Adolescence

Adulthood

Early Death

Disease/Disorder
- Health-Threatening Behavior
- Low Educational Achievement

Biological Embedding during Sensitive Periods

Source: Shonkoff, Boyce & McEwen (2010)
What do we know about the effects of SES on brain development?

- Correlational studies
- Brain imaging studies
• Correlational studies
Study by Kim Noble and Martha Farrah was one of the first to examine the correlations between different cognitive skills and SES

• 150 New York City 1st graders from 9 socioeconomically diverse public elementary schools
• Behavioral testing
• Language (Left perisylvian)
• Executive Function (PFC)
  - Cognitive control – (ACC) ability to self-regulate, cognitive flexibility
  - Working memory - (DLPFC) ability to hold items in the mind
  - Reward processing - (OFC) ability to delay gratification
• Declarative Memory (hippocampus)
• Visuospatial skills (R parietal)
SES composite

- Parental education
- Occupation
- Income
Noble, McCandliss, Farah (2007)

Language
Visuospatial

Memory
Cognitive conflict

Working memory
Reward processing

Noble, McCandliss, Farah (2007)
Fig. 1 – Effect sizes, measured in standard deviations of separation between low and middle SES group performance, on the composite measures of the seven different neurocognitive systems assessed in this study. Black bars represent effect sizes for statistically significant effects; gray bars represent effect sizes for nonsignificant effects.
Consistencies across studies

• SES disparities are not uniform across different neurocognitive systems
• Language system tends to show the strongest effects
• Memory and certain aspects of executive function tend to show smaller but consistent effects
• Brain imaging studies
Family Poverty Affects the Rate of Human Infant Brain Growth

Jamie L. Hanson¹,², Nicole Hair³,⁴, Dinggang G. Shen⁵,⁶,⁷, Feng Shi⁵,⁶,⁷, John H. Gilmore⁸, Barbara L. Wolfe³,⁴,⁹, Seth D. Pollak¹,²

• Repeated assessment of brain development between 5 months and four years of age
• Economically diverse sample (n=77)
• MRI—structural imaging
• Study published in 2013 in PLoS One
Figure 2. This figure shows total gray matter volume for group by age. Age in months is shown on the horizontal axis, spanning from 5 to 37 months. Total gray matter volume is shown on the vertical axis. The blue line shows children from Low SES households; children from Mid SES households are shown in red. The green line shows children from High SES households.

doi:10.1371/journal.pone.0080954.g002
Figure 3. This figure shows frontal lobe gray matter volumes for group by age. Age in months is shown on the horizontal axis, spanning from 5 to 37 months. Total gray matter volume is shown on the vertical axis. The blue line shows children from Low SES households; children from Mid SES households are shown in red. The green line shows children from High SES households.
doi:10.1371/journal.pone.0080954.g003

Figure 4. This figure shows parietal lobe gray matter volumes for group by age. Age in months is shown on the horizontal axis, spanning from 5 to 37 months. Total gray matter volume is shown on the vertical axis. The blue line shows children from Low SES households; children from Mid SES households are shown in red. The green line shows children from High SES households.

doi:10.1371/journal.pone.0080954.g004
Summary of Hanson et al findings

• Infants from low income families had lower volumes of gray matter, in frontal and parietal regions
• No differences in white matter, temporal or occipital loves.
• Differences in brain growth were found to vary with SES, with children from lower-income households having slower trajectories of growth during infancy and early childhood.
Study of 23 healthy 10-year-old children
Wide range of parental SES
Behavioral study as well as MRI
Behaviorally language is most affected by SES
Figure 2. Gray matter volumes correlated with SES. A) VBM results displayed on a customized pediatric brain template; the color scale represents T-values; B) left and right hippocampus volume changes as a function of SES (from SBM).

doi:10.1371/journal.pone.0042486.g002
Figure 3. Left hemispheric anterior frontal regions showing a positive correlation between gyrification index and SES.

doi:10.1371/journal.pone.0042486.g003

Summary of Jednorog et al findings

- Low SES was associated with smaller volume of gray matter in bilateral hippocampi, temporoal gyri
- Local gyrification effects in frontal lobes supportive of a potential developmental lag in low SES children
There Are No Magic Bullets

Positive relationships and quality learning experiences can be promoted both at home and through a range of evidence-based parent education, family support, early care and education, and intervention services.

A balanced approach to emotional, social, cognitive, and language development will best prepare children for success in school and later in the workplace.
Science Points Toward a Two-Tiered Approach to Reducing Disparities

Basic health services and good quality early care and education can promote healthy development and early detection of problems in all children.

Targeted services for children experiencing tolerable or toxic stress can reduce disruptions of the developing nervous and immune systems that lead to later problems in learning, behavior, and health.
Nathan Fox
Distinguished University Professor
University of Maryland

email fox@umd.edu

www.developingchild.harvard.edu