Inequality, Children and Brain Development

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Child Care Council of Nassau
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The Most Complex 3 Pounds in the Universe

• 100 billion neurons at birth
• 250,000-500,000 new neurons per minute in the first months of life
Most growth is not new neurons, but new connections

- Brain connections increasingly complex from birth to 3 years.

.birth 3 months 2 years

1000 trillion connections by age 3
Early Experience Shapes Brain Development

• “Use it or lose it:” connections strengthen or are pruned
• The brain is most “plastic,” or able to make new connections, early in childhood
• Experience varies widely as a function of family social and economic factors
Adversity and the brain

• Extreme adversity is associated with deleterious outcomes
• Relatively less is known about the relationship between more “typical” childhood adversity and brain development

Image courtesy Chuck Nelson
U.S. Poverty Rates by Age Group: 1959 to 2015

- Adults 65 and older
- Adults 18-64
- Children under 18

*Estimates for 2013 and beyond are not directly comparable to previous years due to a re-design of the income questions.


Slide courtesy Benard Dreyer, MD
What is Poverty?

• Varies by family size and composition
• Does not vary geographically
• Family with 2 adults, 2 children
• $ 24,250
• Poverty puts children at risk for a host of negative physical health, mental health, and achievement outcomes
Socioeconomic status (SES) is more than just poverty

- Income
- Parent Education
- Occupation
- Subjective social status
Child SES is strongly associated with cognitive development

- Achievement test scores
- Grade retention
- Literacy
- IQ
- High school graduation
The SES gap emerges early and widens through the elementary years

What factors contribute to the SES gap?

Nutrition
Prenatal care
Perinatal complications
Prenatal drug exposure
Environmental toxicants
Home learning environment
Early education differences
Family Stress
Each of these factors contributes to the link between SES and cognitive skill
“Cognitive skill” is too broad

• Traditional achievement measures not specific in terms of brain function
• Which particular cognitive skills, and corresponding brain areas, are most strongly associated with SES?
Which core cognitive systems are most highly associated with SES?
From kindergarten through adolescence:

Greatest disparities in language, memory, and certain forms of executive function

Noble et al, 2007 Developmental Science
Questions

• How do these differences relate to differences in children’s brain structure?
• How early are SES disparities detectable?
• Which experiences explain SES differences in cognitive and brain development?
• How can this work inform interventions?
How do these differences relate to differences in children’s brain structure?
Higher family income is associated with larger cortical surface area

Noble et al, 2015, Nature Neuroscience
Higher family income is associated with larger cortical surface area

- Relationship strongest among most disadvantaged children
- Variation from person-to-person
- The brain is not destiny

Noble et al, 2015, Nature Neuroscience
How early are effects detectable?

Noble et al, 2015, 
*Developmental Psychobiology*
Children of more highly educated parents have better language skills by 21 months

Noble et al, 2015, *Developmental Psychobiology*
Children of more highly educated parents have better memory skills by 21 months

Noble et al, 2015, *Developmental Psychobiology*
What experiences might explain these differences?
Possible causes

- Nutrition
- Prenatal care
- Prenatal drug exposure
- Perinatal complications
- Environmental toxicants
- Early education differences
- Home language environment
- Family Stress
Theoretical Model

- SES
  - Linguistic environment
    - Left hemisphere language cortex
      - Language
        - hippocampus
          - Memory
        - Prefrontal/Limbic circuitry
          - Cognitive and Emotional Regulation
  - Family Stress
Number of Words Heard by Children Differs Across Income Groups

- Number, complexity and responsiveness of verbal interactions
- Number of words heard is directly related to child vocabulary size

The 30 Million Word Gap
Does the language environment explain SES differences in the brain?
More conversational turns associated with greater surface area in left language cortex (preliminary data)

Melvin, Merz et al, in prep
SES

Linguistic environment

Family Stress

Left hemisphere language cortex

Hippocampus

Prefrontal/Limbic circuitry

Language

Memory

Cognitive and Emotional Regulation
SES

Linguistic environment

Left hemisphere language cortex

Language

Hippocampus

Memory

Prefrontal/Limbic circuitry

Cognitive and Emotional Regulation

Family Stress


Stress can be positive, tolerable, or toxic
What is positive stress?

• Mild or moderate
• Relatively brief
• The individual has some control over the experience
• The experience is buffered by healthy relationships
• Learning to adjust to positive stress is part of healthy development

• Examples:
  – Dealing with frustration
  – Meeting new people
  – Getting a shot
  – Brief separations from parents
What is tolerable stress?

• More severe experiences that have the potential to negatively affect the developing brain
• Generally limited time periods, and therefore effects on the developing brain can be reversible
• Examples:
  – Death or illness of a loved one
  – Frightening accident
  – Divorce
  – Other negative events in the context of ongoing, supportive relationships with adults
What is harmful or “toxic” stress?

• Extreme
• Long-lasting
• Frequent
• Buffering relationships are unavailable
• Such “toxic stress” can lead to damage of body and brain systems
  – Poorly controlled stress-response systems
  – Overly reactive or slow to shut down when faced with threats
  – Children may experience anxiety or feel threatened when no real threat exists
  – Can lead to mental health problems (depression, anxiety, substance abuse) and physical health problems (heart disease, diabetes, stroke)
Lower SES conditions associated with higher family stress

- Socioeconomically disadvantaged children may have altered levels of stress hormones
Does chronic stress explain SES differences in the body and brain?
Higher parent education is associated with reduced parent hair cortisol

Ursache, Merz et al, 2017, Psychoneuroendocrinology
Higher parent education is associated with reduced child hair cortisol.

Holds when adjusting for parent hair cortisol

Ursache, Merz et al, 2017, Psychoneuroendocrinology
Higher family income is associated with reduced parent hair cortisol

Ursache, Merz et al, 2017,
Psychoneuroendocrinology
Resilience:
What protective experiences might buffer these associations?

Image courtesy Center on the Developing Child
http://developingchild.harvard.edu/science/key-concepts/resilience
If experience matters, can this work inform interventions?

And what is the right level at which to intervene?
School-based interventions

• Most common form of intervention addressing SES disparities in achievement
School-based interventions

• Results can be very promising...
• Labor-intensive and costly if done right
• Often suffer from “fadeout”
• If waiting until school, likely waiting too late
Parenting interventions

- SES
- Experience
- Brain
- Cognition
Changing Experience: Parenting interventions

- Traditionally home-based
  - Can be effective...
  - Labor-intensive and costly if done right
  - Challenges due to fadeout, lack of uptake, attrition
  - Difficult to scale up
Changing inequality itself

- SES
- Experience
- Brain
- Cognition
Income boosts can have big effects

- $4,000 increase in annual income between the prenatal year and age 2:
  - 19% increase in adult earnings
  - 160 hour increase in adult work hours
  - Some evidence for improved health in adulthood

*Dahl and Lochner, 2012
Ziol-Guest et al 2012*
First clinical trial of poverty reduction in early childhood

<table>
<thead>
<tr>
<th>National Experiment</th>
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<tbody>
<tr>
<td><strong>Sample</strong></td>
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<tr>
<td><strong>Intervention</strong></td>
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<td><strong>Control</strong></td>
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<td><strong>Assignment</strong></td>
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<td><strong>Payment</strong></td>
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<tr>
<td><strong>Data Collection</strong></td>
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<tr>
<td><strong>Outcomes of interest</strong></td>
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Developmental theory of change

Higher Income

- Increased investment
- Reduced stress

Child cognitive, socio-emotional and brain development
Highly feasible

• Pilot study with 30 low-income moms in NYC
• 93.3% retention over 12 months
• Very few problems with debit card implementation
  – All participants used within one month of recruitment
  – Funds typically spent within two weeks of monthly reload
  – First time using a debit card for 21% of participants
Even in small amounts, money makes a big difference

“Believe it or not even an extra $20 helps... there were times I found myself completely broke... I go and I use it and that [means] I can make it for another week.”

“The money from the card ... really, really helped me out, especially [one] month that we didn’t have the food stamps; we didn’t have anything at all.”
Most moms use the card for the baby

Moms report card payments usually support...

- Baby only: 35%
- All children: 15%
- Entire household: 10%
- Baby and self: 0%
Debit card use: 1112 transactions over 12 months
Intervention group showed preliminary benefits

- Small sample size, but patterns suggest
  - Higher center-based child care expenditures
  - More frequent mother-child activities
  - Less household chaos
  - Less parenting stress
Can boosting family income change children’s trajectories?
% Poverty Over Time: 1959-2014
Seniors vs. Children

![Graph showing poverty rates for seniors and children over time from 1959 to 2015.]

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Slide courtesy Benard Dreyer, MD
Policy implications

• Informs debates on the generosity or cuts to existing or new social service programs that affect families with young children
  – SNAP
  – WIC
  – TANF
  – housing vouchers
  – paid family leave
  – minimum wage

*Income may not be the only or the most important factor in children’s brain development, but it may be most manipulable from a policy perspective.*
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Electroencephalogram (EEG)

- We can measure the electrical activity of the human brain by placing electrodes on the scalp and amplifying the signal.
- This signal can be decomposed into oscillations occurring in different frequency bands.

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<thead>
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<th>Frequency Band</th>
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<td>Gamma: 30-100Hz</td>
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<td>Beta: 12-30Hz</td>
<td>Awake, normal alert consciousness</td>
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Children at-risk for learning and attention disorders tend to exhibit excess low-frequency oscillations and deficit of high-frequency oscillations.

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<td>Gamma: 30-100+Hz</td>
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No socioeconomic disparities in brain function at birth

Brito, Fifer, Myers, Elliott, & Noble, 2016
Developmental Cognitive Neuroscience
Family income associated with increased high-frequency power in the first year of life (prelim data)

N=60
6-to-12-month-old infants
R=.37, p=.04

Brito et al, in prep
Higher maternal stress associated with reduced infant brain activity at 12 months (prelim data)

EEG high frequency power

Perceived stress scale (PSS)

N=10

12-month-old infants

R=-.887; p=.001