Socioeconomic Inequality and Children’s Cognitive & Brain Development

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HCEO Summer School on Socioeconomic Inequality
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Welcome!
Overview

• Introduction
• Primer on neuroscience methods
• SES and the brain
  – Part 1: Behavior
  – Part 2: Brain structure
  – Part 3: Brain function
  – Part 4: Links to achievement and life outcomes
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

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
What is Poverty?

• Varies by family size and composition
• Does not vary geographically
• Family with 2 adults, 2 children
• $ 24,600
• Poverty puts children at risk for a host of negative physical health, mental health, and achievement outcomes
**U.S. Poverty Rates by Age Group: 1959 to 2015**

**Adults 65 and older**
- **21%**

**Adults 18-64**
- **12.4%**

**Children under 18**
- **8.8%**

*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
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

Evans (2004) *American Psychologist*
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 circuits, are most strongly associated with SES?
Which core cognitive systems are most highly associated with SES?
Neuroscience methods

• Brain function
  – Behavior
  – EEG/ERP
  – PET
  – fMRI

• Brain structure
  – MRI
  – DTI
Methodology #1: Neurocognitive behavioral measures

- Executive function
- Visuospatial skills
- Memory
- Language
Neurocognitive testing

• Paper-and-pencil or computer testing
• Relatively inexpensive
• Can be similar to actual classroom activities
• No direct measurement of the brain
Example – Stroop task

PURPLE  YELLOW  RED
BLACK  RED  GREEN
RED  YELLOW  ORANGE
BLUE  PURPLE  BLACK
RED  GREEN  ORANGE

Prefrontal cortex
How does socioeconomic disadvantage relate to neurocognitive performance?

Noble et al, 2007 Developmental Science
But what about directly measuring the brain?
Methodology #2: Electroencephalogram (EEG)

- Can measure the electrical activity of the human brain by placing electrodes on the scalp and amplifying the signal.
- Changes in voltage can then be plotted over a period of time.
EEG signal

- EEG signal can be decomposed into oscillations occurring in different frequency bands
EEG

- Relatively inexpensive and noninvasive
- Outstanding temporal resolution
- Relatively poor spatial resolution
- Just measures the brain at rest, not while doing any particular cognitive activity
- But can be correlated with performance on cognitive tests or other characteristics
For example, learning and attention disorders tend to exhibit

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Deficit of high-frequency oscillations

Excess low-frequency oscillations
EEG

• Can choose a particular frequency band and “map” it across the scalp
• Can compare differences in frequency bands between groups
Children with family history of language impairment have less high-frequency activity at the front and sides of the brain.

Can “map” each frequency band to show which scalp areas have the highest power in that frequency band.

Benasich et al, 2008
Children whose parents have higher-prestige occupations have more high-frequency EEG power toward the front of the brain.

Tomalski et al., 2013
EEG is measured while the child is “at rest”

• But what about measuring the brain when the child is engaged in a cognitive task?
Methodology #3: Event-Related Potentials (ERP)

- ERP measures neural response to a particular set of stimuli, such as words or pictures.
- Multiple trials of a type of stimulus are presented and then averaged over trials.
- Reduces noise from unrelated variation in brain electrical activity.
- Plotted with negative voltages upward.
- Certain components of the waveform have classic associations with function.

Novel stimulus perception; decreases with repetition.

More active decision making about a stimulus; seen in oddball paradigms.
Dichotic listening paradigm

Stevens et al., 2009, Developmental Science
Children of higher educated mothers better able to suppress distracting stimuli

*Stevens et al., 2009, Developmental Science*
But these squiggly lines don’t look like brains at all!
Methodology #4: Structural MRI
How MRI works

1. Atoms spin in random directions, like tops, around their individual magnetic fields.
2. In magnetic field produced by MRI, atoms line up either north or south. About half the atoms go each way, but there are a few unmatched atoms.
3. When radio frequency pulse is applied, the unmatched atoms spin the other way.
4. When the radio frequency is turned off, the extra atoms return to normal position, emitting energy.
5. The energy sends a signal to a computer. The computer uses a mathematical formula to convert the signal into an image.
MRI

• Very strong magnet, about 10K times the strength of the Earth’s magnetic field
• Excellent spatial resolution (millimeters)
• Non-invasive
  – No radiation
  – But loud, may be uncomfortable
• Can correlate anatomical measurements with cognitive performance or other characteristics
Higher family income is associated with greater hippocampal volume

Noble et al, 2012, Developmental Science
Diffusion tensor imaging

- MRI-based neuroimaging technique
- Measures the location, orientation, and “fractional anisotropy,” or integrity, of white matter tracts
Diffusion tensor imaging

- Children who experienced early extreme neglect (institutionalization) show differences in the integrity of numerous white matter tracts
- This is partially ameliorated among children who were placed in early foster care

Bick et al., 2015, JAMA Pediatrics
Can we have pretty pictures of the brain that tell us about what the brain is *doing*?

**Structural MRI vs. Functional MRI**

*Structural MRI* reveals brain *anatomy*.  

*Functional MRI (fMRI)* reveals brain *function*. 
Methodology #5: Functional MRI (fMRI)

• In response to an increase in neuronal activity, local oxygenation increases ➔ more intense MR signal

• Can measure the blood-oxygen level dependent (BOLD) signal at thousands of points in the brain
Functional MRI (fMRI)

- Experimental condition
- Control condition
- Experimental condition
- Control condition

combined area under graphs = convolution at time $T = \text{BOLD response}$

$T_1$ and $T_2$
Functional MRI (fMRI)

- Can map which areas respond according to the predicted model.
Functional magnetic resonance imaging (fMRI)

- Excellent spatial resolution
- Moderate temporal resolution (seconds)
- Non-invasive
  - No radiation
  - But loud, may be uncomfortable
- Directly measures brain function
- However, experience of doing a task in the scanner may be very different from doing a task in real life
An example: Stroop task

combined area under graphs = convolution at time T = BOLD response

time $T_1$  time $T_2$
Stroop task:
Prefrontal cortex activation greater in inhibition vs. control condition

Adelman et al 2002 Neuroimage
Typically developing children show a stronger amygdala response to their mother’s face than a stranger’s face. But children who experienced severe early neglect did not, even once adopted into new homes.
SES and the Brain
Part 1: Behavior
From kindergarten through adolescence:

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

Noble et al., 2007 *Developmental Science*
Do socioeconomic gradients exist in developing countries?

• Madagascar
  – 68% of the country below the international poverty line
  – Gross national income per capita $340

• 1232 children age 3-6
  – Nationally representative sample of rural and urban communities

Fernald et al, 2011
Socioeconomic gradients in child development in a very low income population

How early are effects detectable?

• 179 infants from socioeconomically diverse families
  – 9, 15, 21 months
  – Administered commonly used tests of infant language and memory development
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
Socioeconomic disparities in toddler language development

- 48 English learning infants followed longitudinally from 18 to 24 months
- Two SES groups
  - Lower SES: average maternal ed 13.2
  - Higher SES: average maternal ed 16.7
- Language measures at 18 & 24 months:
  - Macarthur-Bates Communicative Development Inventory
  - Looking-while-listening paradigm

Fernald, Marchman & Weisleder, 2013, Developmental Science
Looking while listening
At 18 months, higher SES associated with...

- Higher vocabulary
- Higher accuracy
- Faster speed

Fernald, Marchman & Weisleder, 2013, *Developmental Science*
Children from lower SES homes are 6 months behind by 24 months of age

- Both speed and reaction time are associated with vocabulary

Fernald, Marchman & Weisleder, 2013, *Developmental Science*
Are these SES differences the result of differences in experience?

- Adopted children
- Timing: early childhood poverty is worse than later childhood poverty
- Responsiveness to intervention suggests experience-based resilience
Are these SES differences the result of differences in experience?

- **Monozygotic** twins: share all genes
- **Dizygotic** twins: share half genes
Twin Studies

• IQ in twins
  – Higher SES: Genetic factors account for more variation
  – Lower SES: Environmental factors account for more variation

Turkheimer et al 2003
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
- Home language environment
- Family Stress
- Left hemisphere language cortex
- Hippocampus
- Prefrontal/Limbic circuitry
- Language
- Memory
- Cognitive and Emotional Regulation
SES and the brain part 2: Brain structure
PING Study

- 1099 children and adolescents
- Ages 3-21 (mean 11.9)
- Diverse sample from 10 sites across the US
  - Average parent education some college (<7 – >16)
  - Mean household income ~$98k (<$5k - >$300k)
- Examined various aspects of brain structure
- Controlled for genetically-defined race

Noble et al, 2015,
Nature Neuroscience
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 is strongest among most disadvantaged children
- Variation from person to person

Noble et al, 2015, *Nature Neuroscience*
Income moderates age-related difference in cortical thickness

Piccolo, Merz et al, 2016, *PLOS One*
Does it matter?
Surface Area Partially Mediates Links between SES and Executive Function

Income → Surface Area

Surface Area → Inhibitory Control

Noble et al, 2015, *Nature Neuroscience*
Surface Area Partially Mediates Links between SES and Executive Function

Noble et al, 2015, *Nature Neuroscience*
Brain structure is associated with achievement in adolescence

Differences in brain structure account for 15-44% of the income-achievement gap

Mackey et al, 2015, Psychological Science
Hair et al, 2015, JAMA Pediatrics
Home language environment

Left hemisphere language cortex

Hippocampus

Prefrontal/Limbic circuitry

Language

Memory

Cognitive and Emotional Regulation

SES

Family Stress
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 turn associated with greater surface area in left language cortex

- Partially mediates socioeconomic disparities in reading skill
- No link between brain structure and total number of adult words or child vocalizations

Merz, et al, under review
SES

Home language environment

Left hemisphere language cortex

Language

Family Stress

Hippocampus

Memory

Prefrontal/Limbic circuitry

Cognitive and Emotional Regulation
SES

Home language environment

Family Stress

Left hemisphere language cortex

Hippocampus

Prefrontal/Limbic circuitry

Language

Memory

Cognitive and Emotional Regulation
What is stress?

• Novel or threatening situation that increases heart rate, blood pressure, and stress hormones (i.e., cortisol)
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)
Toxic Stress Derails Healthy Development

• Harvard Center for the Developing Child

• http://developingchild.harvard.edu/resources/toxic-stress-derails-healthy-development/
Hypothalamus-Pituitary-Adrenal (HPA) axis
HPA Axis function / dysfunction

• When cortisol is released suddenly and turned off quickly
  – Mobilizes energy, enhances memory, activates immune response

• If stress is chronic and cortisol release is dysregulated,
  – Immune function can be suppressed
  – Memory suppression
  – Metabolic syndrome, bone loss, muscle atrophy
Three brain regions dramatically affected by stress

- Hippocampus
- Amygdala
- Prefrontal cortex
Hippocampus

• Essential for
  – Memory
  – Navigation

• High levels of glucocorticoid receptors
How does stress influence hippocampus development?
Animal studies

• Stress or stress hormone application
  – Suppresses neurogenesis
  – Alters neurotransmitter activity
  – Dendritic remodeling
  – Smaller hippocampal volumes
  – Learning tasks dependent on the hippocampus
Rodent model of maternal care: Licking and grooming

Champagne et al., 2008, Journal of Neuroscience
Natural variation in LG behavior

• Offspring of low LG mothers show
  – Increased HPA responses to stress
  – Enhanced emotionality
  – Impaired performance on spatial learning and object recognition tasks

• These effects are reversed if offspring of low LG mothers are “cross-fostered,” i.e., reared by high HG mothers
How does maternal care affect features of the hippocampus?

- Morphology (structure) of hippocampal neurons
- Long-term potentiation (LTP) in vitro
- Behavioral (learning/memory) performance

Champagne et al., 2008, Journal of Neuroscience
How is stress associated with hippocampal structure in humans?

• In people, can’t measure cellular structure or function

• But can measure hippocampal volume (MRI)

Gianaros et al., 2007, NeuroImage
Higher perceived stress associated with smaller hippocampal volumes

- Adjusted for age, total gray matter volume, time since menopause, use of hormone therapy, depressive symptoms, educational attainment, BMI, smoking and alcohol history

Gianaros et al., 2007, NeuroImage
Other human studies

- Acute and chronic stress impairs function of hippocampus
- Stress may reduce hippocampal volume
  - PTSD
  - Healthy middle-aged and older adults
  - Some evidence in children
- ...Or small hippocampal volume may predispose to experience stress differently?

Tottenham and Sheridan 2010, Arnsten 2009
SES

Home language environment

Family Stress

Left hemisphere language cortex

Hippocampus

Prefrontal/Limbic circuitry

Language

Memory

Cognitive and Emotional Regulation
Socioeconomic disadvantage associated with higher family stress

- Socioeconomically disadvantaged children may have altered levels of stress hormones
Higher family income is associated with greater hippocampal volume.

Noble et al, 2012, Developmental Science
Does chronic stress explain SES differences in the 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 nonlinearly associated with reduced parent hair cortisol

Ursache, Merz et al, 2017, Psychoneuroendocrinology
Higher child hair cortisol associated with reduced hippocampal volume

Specifically in CA3 and the dentate gyrus

Merz et al, under review
Child stress partially explains link between family SES and children’s hippocampal volume

Merz et al, under review
Income and hippocampal volume: mediated by parenting, stress

Luby et al., 2013
Is childhood SES or adult SES driving brain development?

• 238 64-65-year-olds born in 1936
• Collected childhood SES at age 64
  – Number of “public rooms” in the family home
  – Number of people asked to share a bathroom
  – Paternal occupation when the individual was 11 years old
• Adult SES
  – Number of years of education the participant received
  – Participant’s occupation
  – “Local area deprivation” based on home address

Staff et al, 2012
Is childhood SES or adult SES driving brain development?

- Childhood SES was associated with hippocampal volume, adjusting for covariates
- Adult SES was not

Staff et al, 2012
Make no mistake...

- Poverty is associated with early exposure to chronic stress, in ways that we believe are harmful to the developing brain.
- This effect is much less severe than the profound harm caused by depriving young children of their families.
- The science is clear that isolating children from families leads to abnormal health and development.
- Nurturing relationships are absolutely fundamental to normal human development and resilience.
- Abusive policy is likely to have long-term effects on the physical and mental health of these children.
BREAK
SES and the brain Part 3: Brain function
(It’s not all about looks...)
How early are effects detectable?

- Behavior: second year of life
- Brain: first year of life
Children of more highly educated parents have better language skills by 21 months
Children of more highly educated parents have better memory skills by 21 months

Noble et al, 2015, Developmental Psychobiology
On EEG, 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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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

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

Brito et al, *in prep*
Event-Related Potentials (ERP)

- ERP measures neural response to a particular set of stimuli, such as words or pictures.
- Multiple trials of a type of stimulus are presented and then averaged over trials.
- Reduces noise from unrelated variation in brain electrical activity.
- Plotted with negative voltages upward.
- Certain components of the waveform have classic associations with function.
Does family SES relate to a child’s ability to pay attention to relevant information and ignore distracting information?
Dichotic listening paradigm

Stevens et al., 2009, Developmental Science
Family SES and selective attention

- 32 healthy 3-to-8-year-olds
- Mostly white
- At least 25\textsuperscript{th} percentile on language composite
- Maternal education used as SES measure
  - Higher maternal ed: at least one year of college
  - Lower maternal ed: no more than high school
- Recorded ERPs while listening to the two stories

Stevens et al., 2009, Developmental Science
Higher Parental Education Group

Lower Parental Education Group

Stevens et al., 2009, Developmental Science
Children of higher educated mothers better able to suppress distracting stimuli

Stevens et al., 2009, Developmental Science
Training can improve children’s selective attention

Neville et al., 2013, PNAS
Executive function and emotion regulation

Executive Function

Fear, Anxiety, Anger
Emotion regulation is a balance between the amygdala and prefrontal cortex

- The amygdala detects and responds to threats from the environment, activating physiological stress responses
- The PFC is a “top-down” regulator of the amygdala in adulthood
- Increased activity in parts of the PFC associated with
  - Diminished amygdala activity to negative stimuli
  - Diminished negative affect
- Aberrant PFC-amygdala regulation thought to underscore impaired emotion regulation in psychiatric disorders such as depression, anxiety and disorders of impulsivity
Does childhood poverty predict adult emotion regulation?

- Examined associations between childhood poverty at age 9 and adult neural circuitry during emotion regulation at age 24.
- N=49
- Rural sample
- Longitudinal assessments – ages 9, 13, 17
- Measured chronic stress as a mediator:
  - Psychosocial risk: child-family separation, violence, family turmoil
  - Physical risk: noise, crowding, housing quality
  - Maternal and child report, observer report
- Emotion regulation measured as cognitive reappraisal

Kim et al PNAS 2013
Cognitive reappraisal
Questions:
1. Are there areas that respond differently during reappraisal vs. control condition?
2. Are these differences related to childhood SES?
Childhood income related to increased PFC and decreased amygdala activation during emotion regulation in adulthood

Held when controlling for adult income

Kim et al., 2013
Link between childhood poverty and adult prefrontal function mediated by chronic stress
If experience such as the home language environment or family stress matters, can this work inform interventions?
SES and the brain Part 4: Links to achievement and life outcomes

“The most efficient strategy for strengthening the future workforce, both economically and neurobiologically, and improving its quality of life is to invest in the environments of disadvantaged children during the early childhood years.”

Knudsen, 2006, *PNAS*
Interventions in early childhood have a higher rate of return than later interventions

Knudsen, 2006, PNAS
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
Academic and economic outcomes are improved following high-quality preschool

Knudsen, 2006, *PNAS*
Chicago School Readiness Project

• Cluster-randomized control trial in Head Start settings in some of Chicago’s poorest neighborhoods
  – Comprehensive classroom-based intervention targeting emotional and behavioral adjustment
  – Extensive training and support for teachers on effectively managing children’s dysregulated behavior

Raver et al 2011 Child Development
Impacts on Executive Functions

Impacts on Language and Math
(though not explicitly targeted)

SOURCE: Raver, Jones, Li-Grining, Zhai, Bub, & Pressler (2011), Child Development.
NOTES: Significance levels are indicated as * p < 0.10; ** p < 0.05; *** p < 0.01.
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
Changing Experience: 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

[Diagram]

SES → Experience → Brain → Cognition
Intervening most distally: Changing SES itself
Income boosts can have big effects

• $4,000 increase in annual income between the prenatal year and age 2:
  – increased adult earnings
  – increased time in the labor force
  – Some evidence for improved health in adulthood

• But can we move past correlation to understand if income is causing these differences?

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

- 1000 low-income mothers recruited in hospital after giving birth
- All participants receive unconditional cash transfer for 40 months
  - Treatment group: $333/month ($4000/year)
  - Control group: $20/month ($240/year)
- Monthly reload via debit card
- Causal impact on children’s cognitive, emotional and brain development
  - Age 1 & 2: Home visit with survey, observation/video of parenting, stress physiology, cognitive development
  - Age 3: Lab visit with in-depth assessments of children’s cognitive, emotional and brain development
- Funded by NIH and a consortium of foundations
- Launched May, 2018!
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
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**: 20%
- **Entire household**: 25%
- **Baby and self**: 30%
Debit card use: 1112 transactions over 12 months
Intervention group showed preliminary benefits relative to control group

- 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?
Size of Public Spending on Children and Families

Slide courtesy Benard Dreyer, MD
% POVERTY OVER TIME: 1959-2014
SENIORS VS. CHILDREN

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<th>Seniors (65+)</th>
<th>Children (0-18)</th>
</tr>
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<td>1959</td>
<td>35</td>
<td>25</td>
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<tr>
<td>1969</td>
<td>27</td>
<td>14</td>
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<td>1979</td>
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<td>1989</td>
<td>11</td>
<td>20</td>
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<tr>
<td>2015</td>
<td>9</td>
<td>21</td>
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Slide courtesy Benard Dreyer, MD
Policy implications

• Has the potential to provide direct evidence of the effects of poverty reduction on the developing brain and mind

• 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 the only or the most important factor in children’s brain development, but it may be most manipulable from a policy perspective.
Acknowledgements

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Neurocognition, Early Experience, and Development (NEED) Lab

www.columbia.edu/cu/needlab

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- Hirokazu Yoshikawa, Ph.D., NYU
- William Fifer, Ph.D., Columbia
- Natalie Brito, Ph.D., NYU
- Luciane Piccolo, Ph.D., SUNY-Stonybrook
- Nathan Fox, Ph.D., UMD
- Alexandra Ursache, Ph.D., NYU
- Elizabeth Sowell, Ph.D., USC

Anonymous
Amygdala

- Essential for experiencing emotions
- Also has a high number of glucocorticoid receptors
How does stress influence amygdala development?
Stress and amygdala: Animal studies

• Chronic stress
  – leads to cellular changes in the amygdala
  – Augments amygdala-based startle response

• Poor caregiving accelerates amygdala development

Tottenham and Sheridan 2010
Stress and amygdala: Human studies

- Prolonged childhood stress associated with larger amygdala volume

Tottenham and Sheridan 2010
Tottenham et al 2009
Gee et al 2013
Stress and amygdala: Human studies

- Prolonged childhood stress associated with early maturation PFC-amygdala functional connectivity

Tottenham and Sheridan 2010
Tottenham et al 2009
Gee et al 2013
Prefrontal cortex
PFC is essential for self-regulation

The deliberate control of ... 

... in order to meet specific goals.
Improves dramatically in early childhood, but continues to show improvement through adolescence.

(Center on the Developing Child, 2011)
How does stress influence prefrontal cortex development?
Stress and PFC: Animal studies

- Repeated exposure to stress
  - Synapse loss
  - Changes in dendritic branching

- Morphological changes predictive of worse performance on animal analogues of human executive functioning tasks

Liston et al. 2006
In humans, higher perceived stress associated with smaller right orbitofrontal cortex

Gianaros et al., 2007, NeuroImage
SES, chronic stress, and working memory

• 195 young adults
• Longitudinal study of rural poverty, cumulative risk, and child development
• Half grew up below the poverty line
• Duration of poverty birth through age 13
• Chronic stress on the body (“allostatic load”) - BP, stress hormone levels, body mass index measured at 9 & 13
• Working memory assessed at age 17

Evans and Schamberg, 2009
SES, Stress, and Working Memory

Proportion of childhood in poverty

- Poverty ➔ allostatic load ➔ working memory

Evans and Schamberg, 2009