

# Inequality, Children and Brain Development

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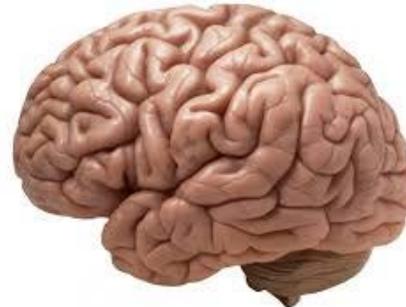
INRICH Conference

Cornell University

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# Biological Pathways in Childhood Poverty: Discussion

- This morning's excellent overview of socioeconomic disparities
  - Definitions
  - Rates
  - What we mean by mechanisms
  - Effects on physical health
- Socioeconomic differences in cognitive and brain development



# 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



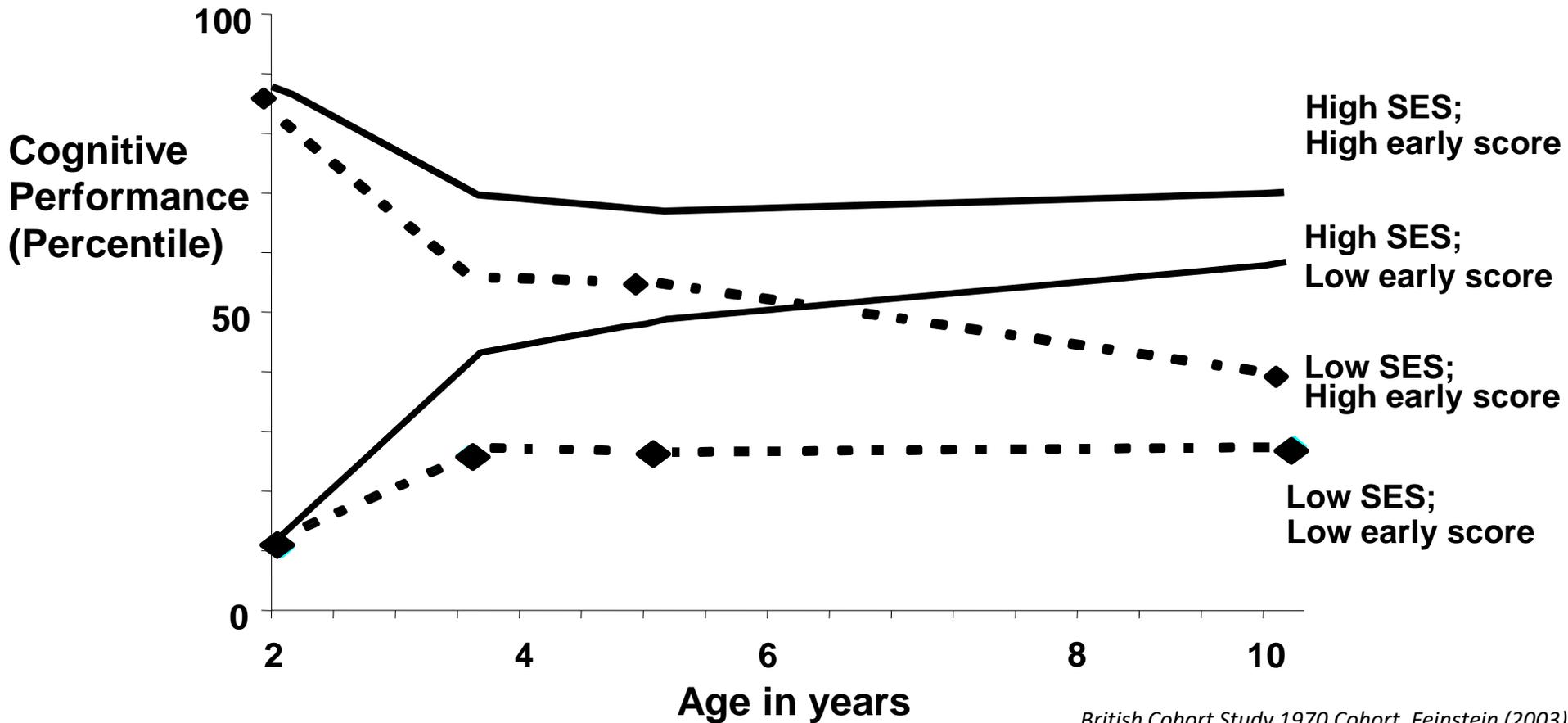
# Child SES is strongly associated with cognitive development

- 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



*British Cohort Study 1970 Cohort, Feinstein (2003)*

# What factors contribute to the SES gap?

Environmental toxicants

Nutrition

Prenatal care

Perinatal complications

Prenatal drug exposure

Home learning environment

Early education differences

Family Stress

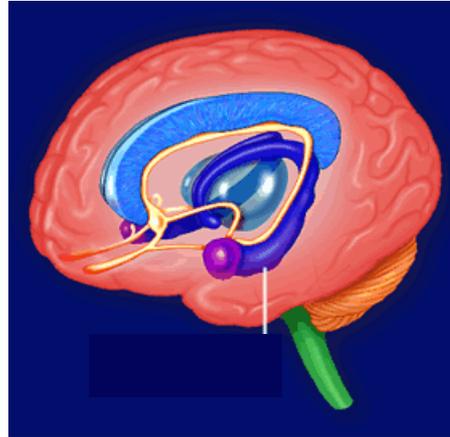


Each of these factors contributes to the link between SES and cognitive skill

# “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?

Executive  
function



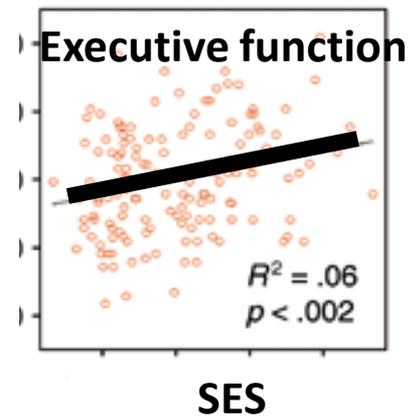
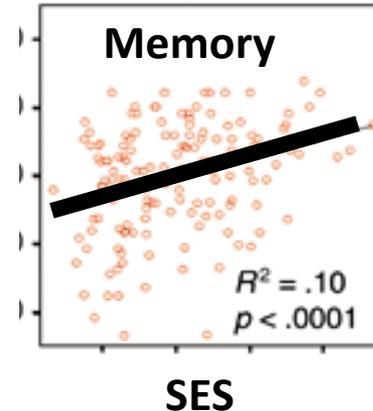
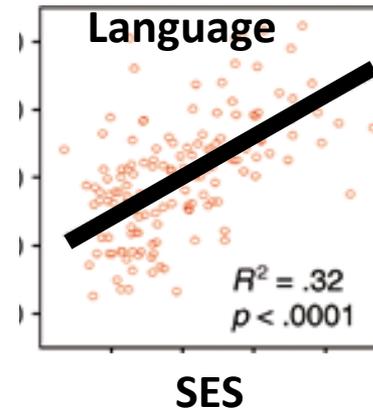
Visuospatial  
skills

Memory

Language

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

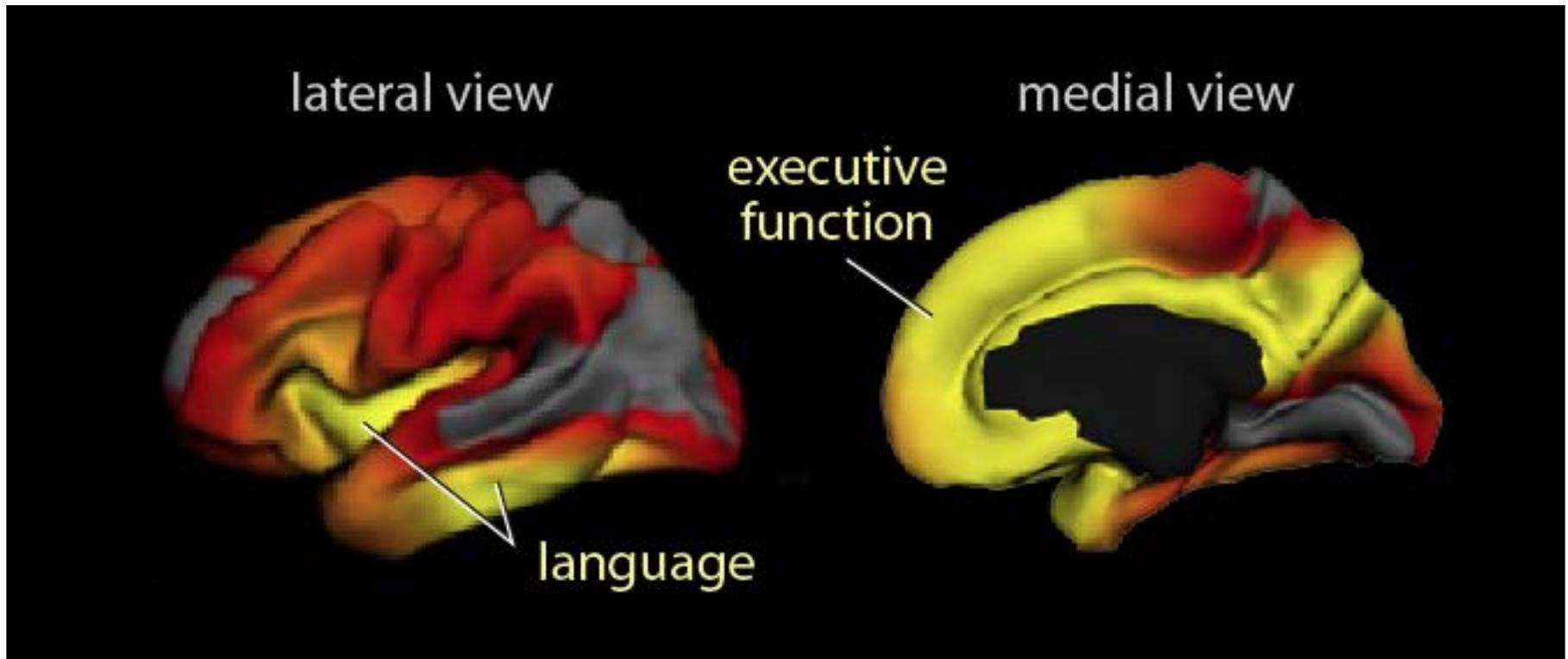


# Questions

- 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?

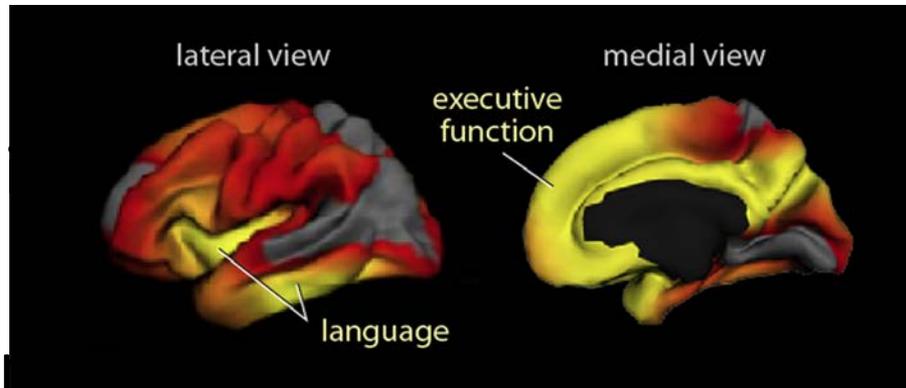
Higher family income is associated with larger cortical surface area



Noble et al, 2015,  
*Nature Neuroscience*

Higher family income is associated with larger cortical surface area

- Relationship between family income and cortical surface area in children
- Variation in cortical surface area across different socioeconomic groups



Advantaged

Noble et al, 2015,  
*Nature Neuroscience*

Does it matter?

# Brain structure is associated with achievement

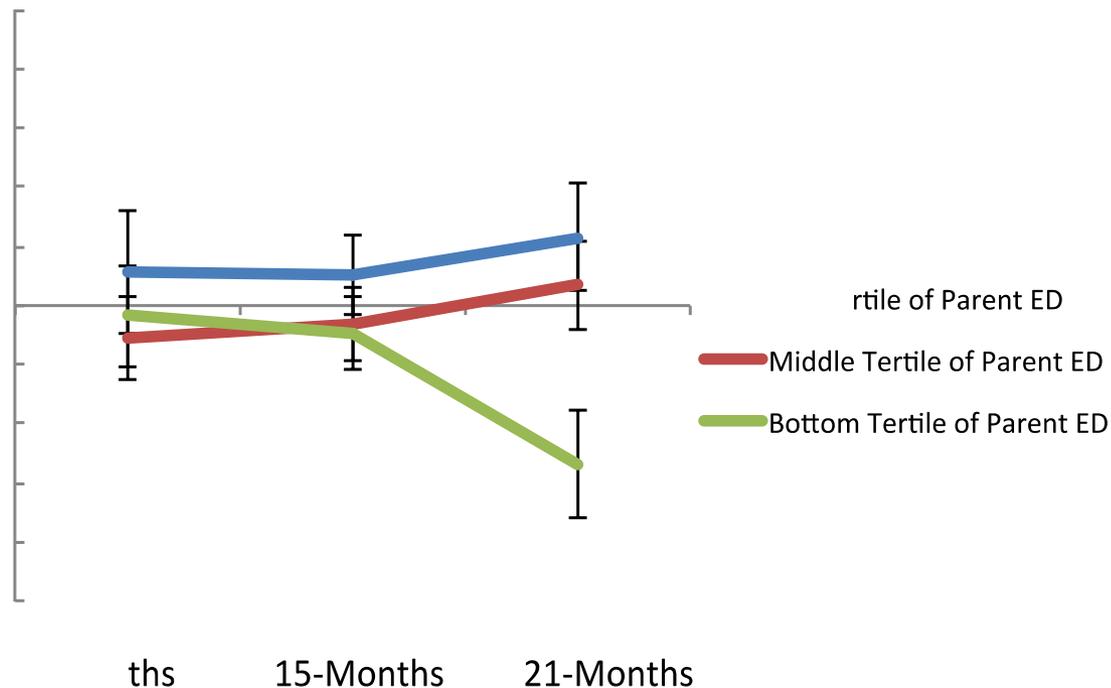
Differences in brain structure account for 15-44% of the income-achievement gap

Mackey et al, 2015, *Psychological Science*

Hair et al, 2015, *JAMA Pediatrics*

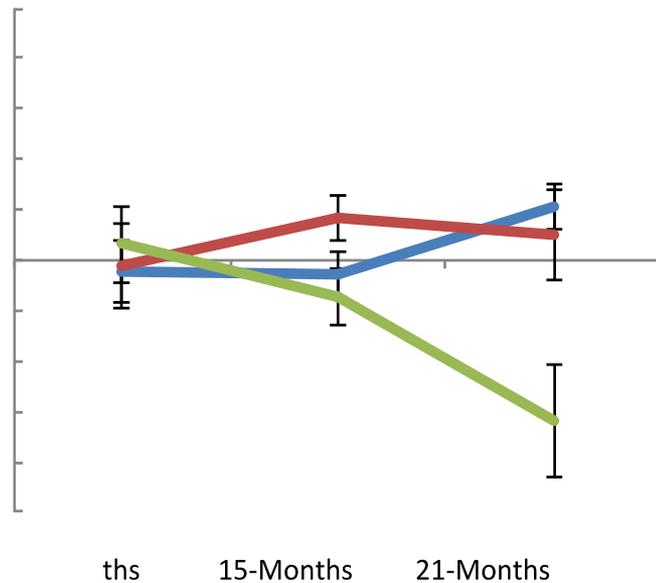
How early are effects detectable?

# Children of more highly educated parents have better language skills by 21 months



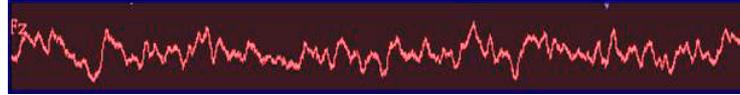
Noble et al, 2015,  
*Developmental Psychobiology*

# Children of more highly educated parents have better memory skills by 21 months



Noble et al, 2015,  
*Developmental Psychobiology*

# Electroencephalogram (EEG)

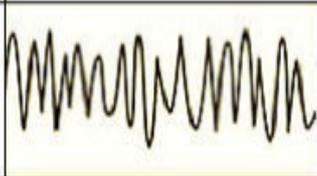
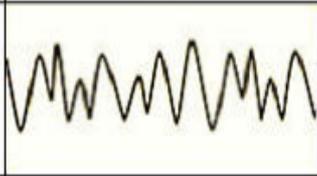
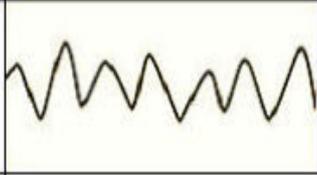
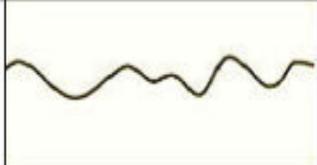


- We can measure the electrical activity of the human brain by placing electrodes on the scalp and amplifying the signal
- This signal can be decomposed into oscillations occurring in different frequency bands



<b>Gamma: 30-100+Hz</b> Peak performance, flow	
<b>Beta: 12-30Hz</b> Awake, normal alert consciousness	
<b>Alpha: 8-12Hz</b> Relaxed, calm, lucid, not thinking	
<b>Theta: 4-7Hz</b> Deep relaxation and meditation, mental imagery	
<b>Delta: .1-4Hz</b> Deep, dreamless sleep	

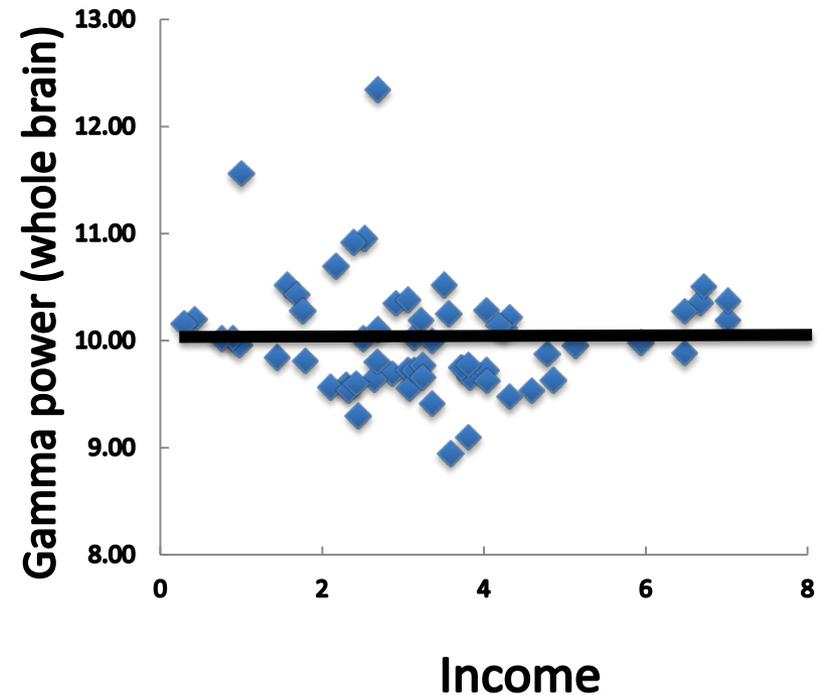
# Children at-risk for learning and attention disorders tend to exhibit

<b>Gamma: 30-100+Hz</b> Peak performance, flow	
<b>Beta: 12-30Hz</b> Awake, normal alert consciousness	
<b>Alpha: 8-12Hz</b> Relaxed, calm, lucid, not thinking	
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**Deficit of high-frequency oscillations**

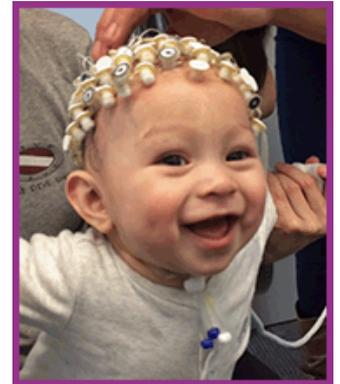
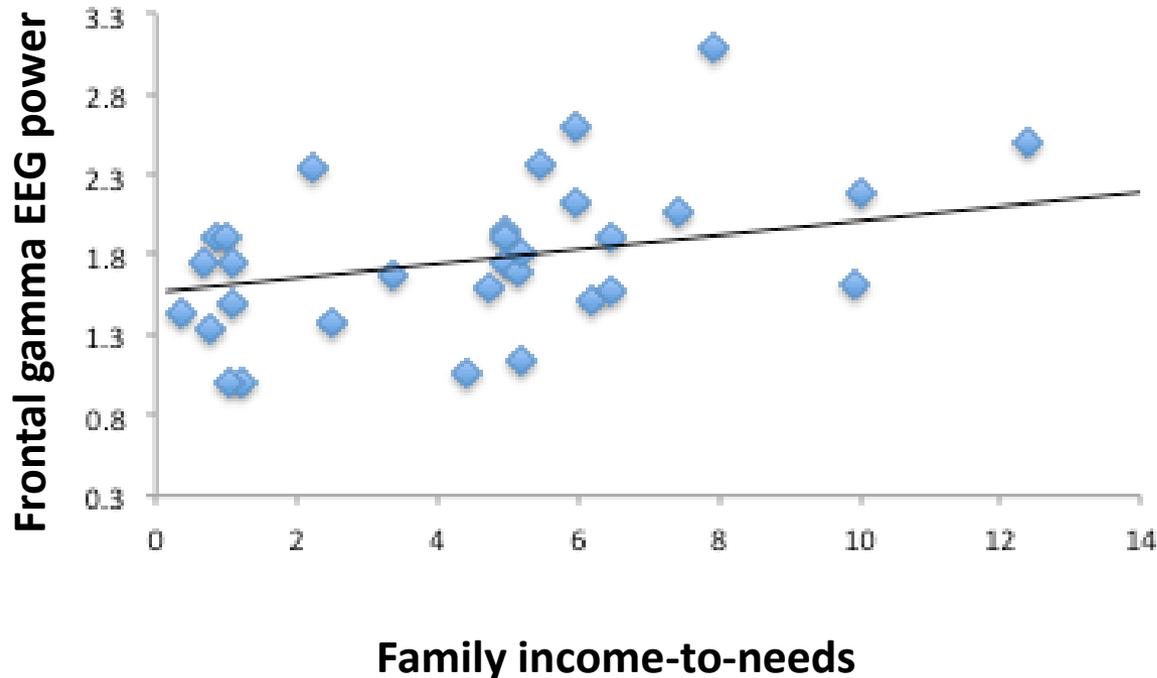
**Excess low-frequency oscillations**

# 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*

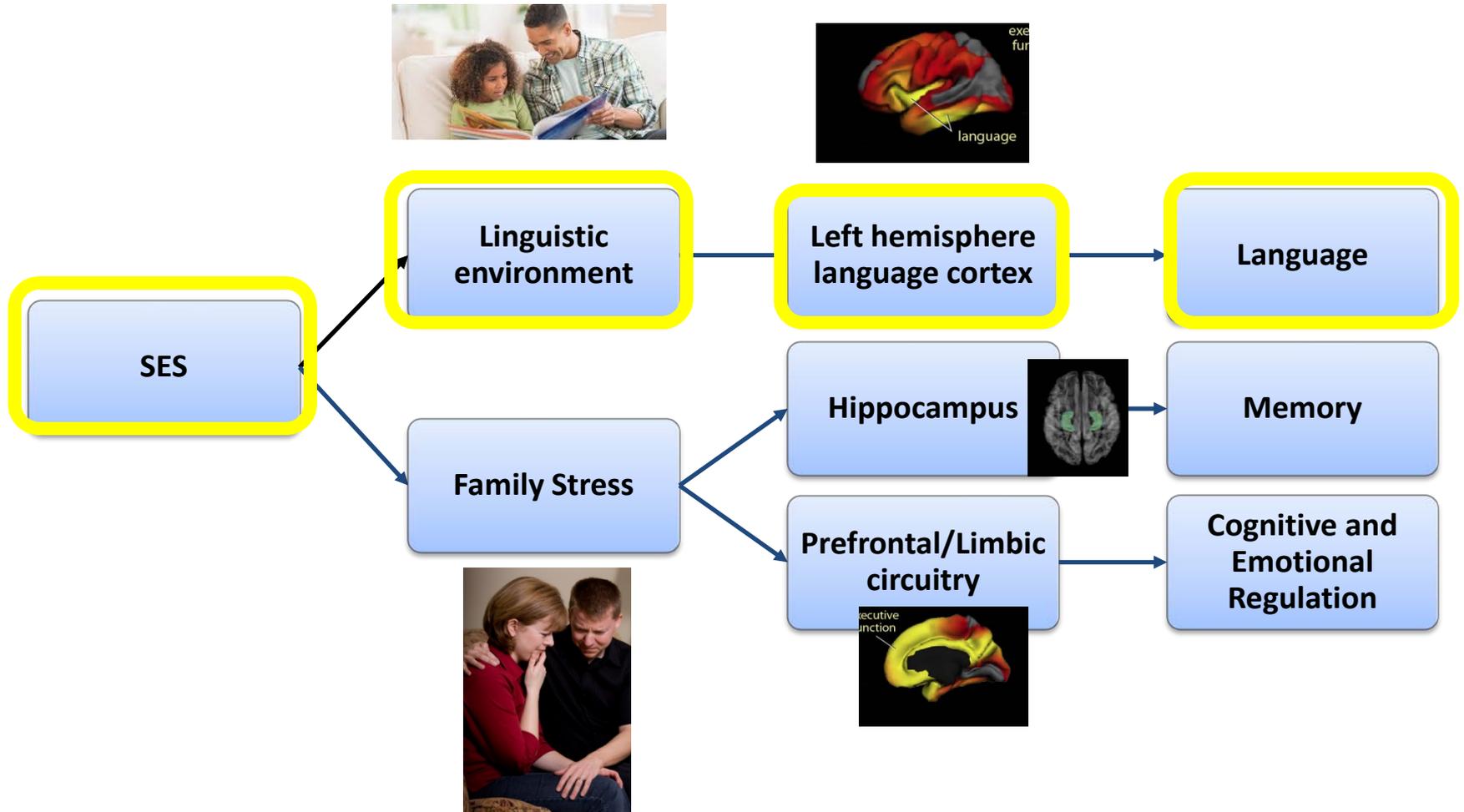
What experiences might explain these differences?

# Possible causes

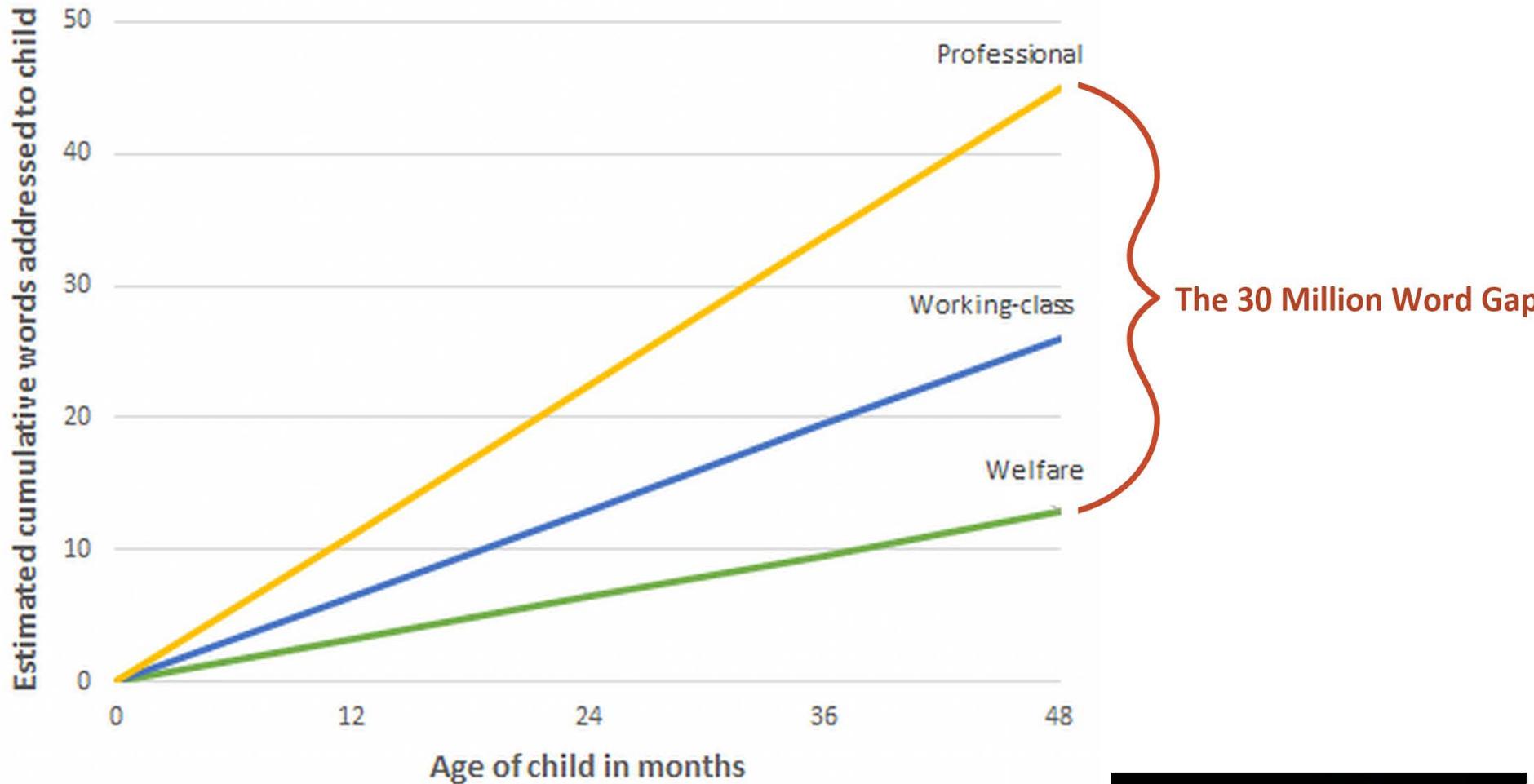
- Nutrition
- Prenatal care
- Prenatal drug exposure
- Perinatal complications
- Environmental toxicants
- Early education differences
- Home language environment
- Family Stress



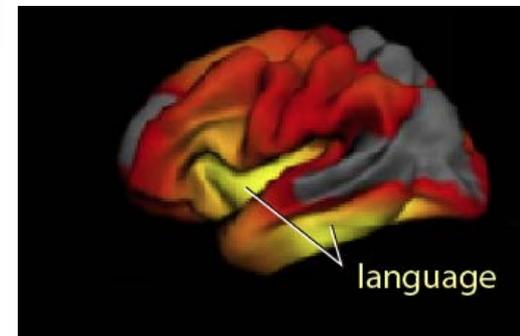
# Theoretical Model



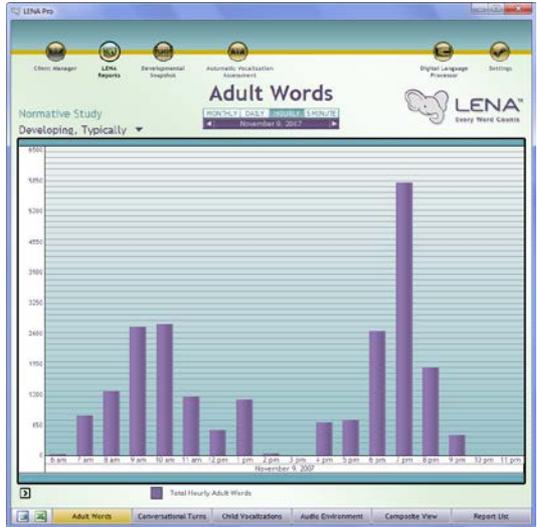
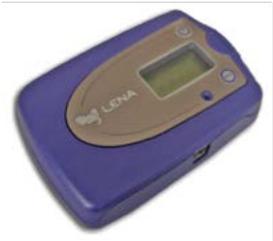
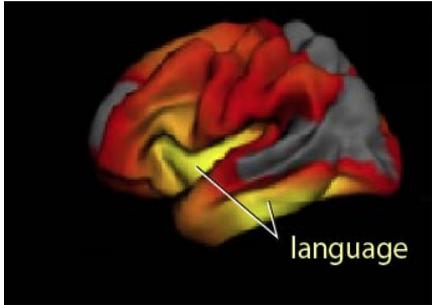
# Number of Words Heard by Children Differs Across Income Groups



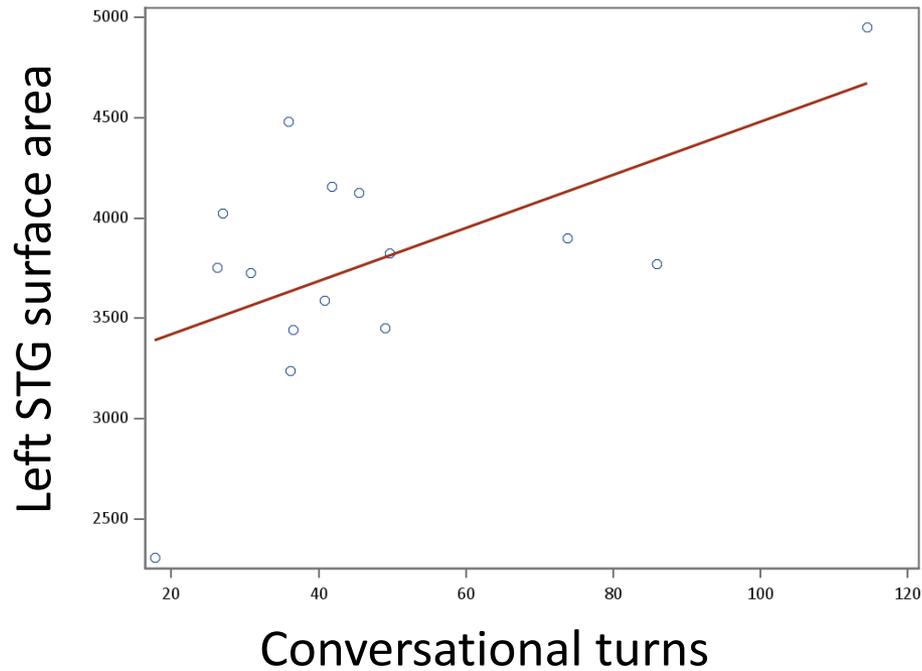
- Number, complexity and responsiveness of verbal interactions
- Number of words heard is directly related to child vocabulary size

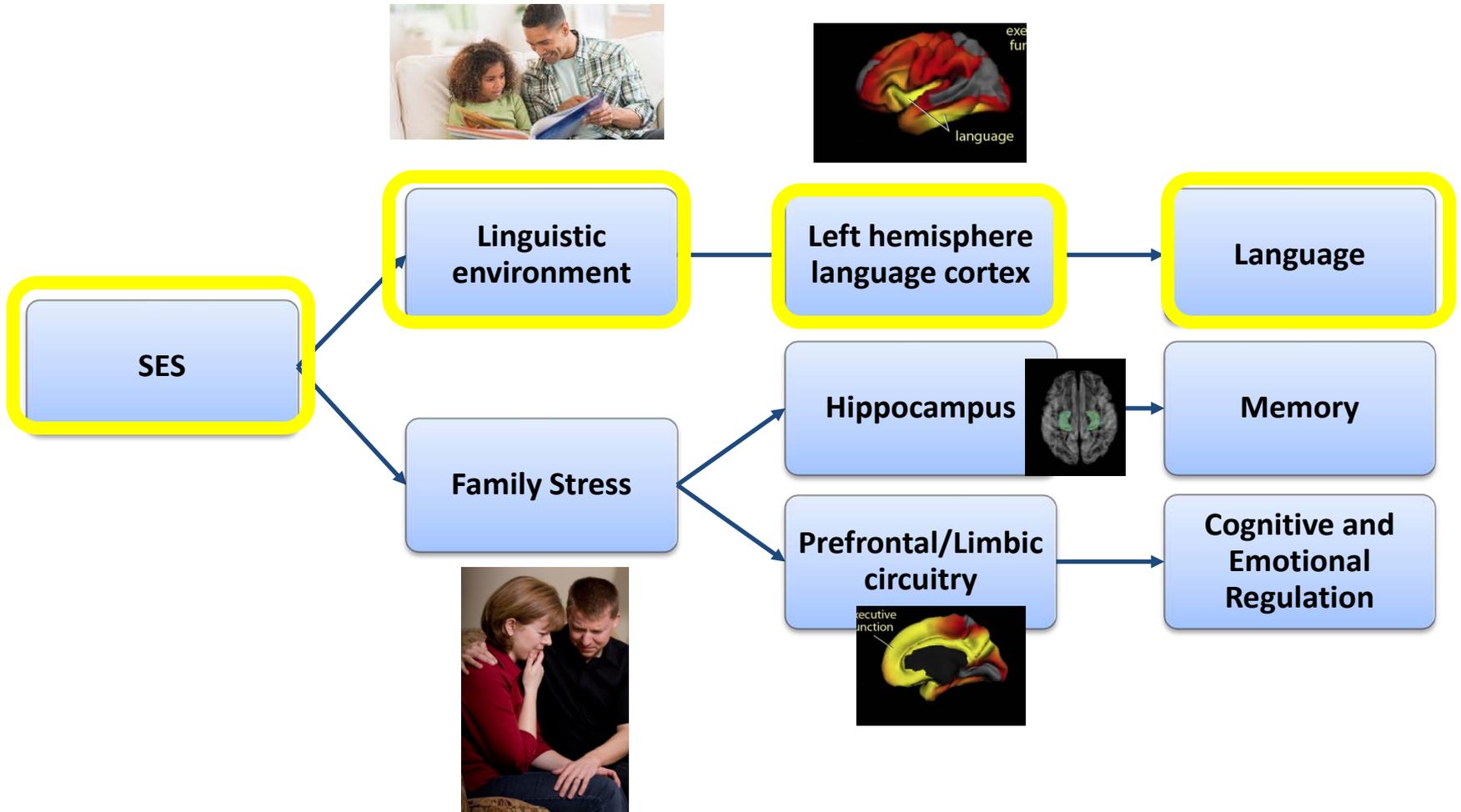


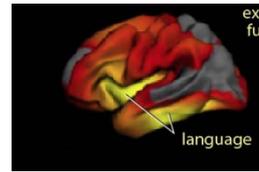
# Does the language environment explain SES differences in the brain?



# More conversational turns associated with greater surface area in left language cortex







SES

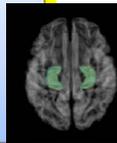
Linguistic environment

Left hemisphere language cortex

Language

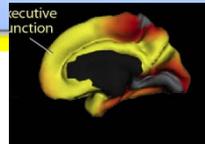
Family Stress

Hippocampus



Memory

Prefrontal/Limbic circuitry



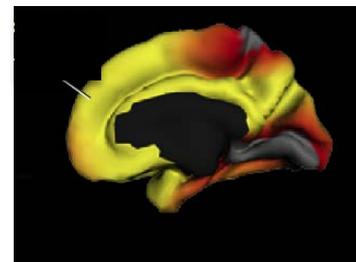
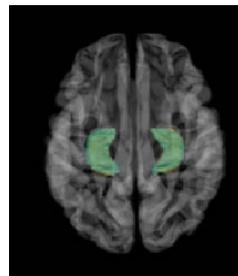
Cognitive and Emotional Regulation



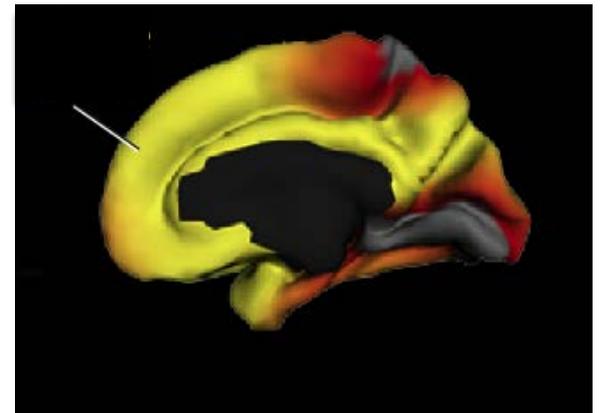
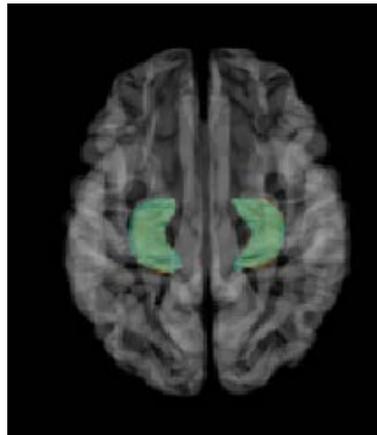
# Lower SES conditions associated with higher family stress



- Socioeconomically disadvantaged children may have altered levels of stress hormones

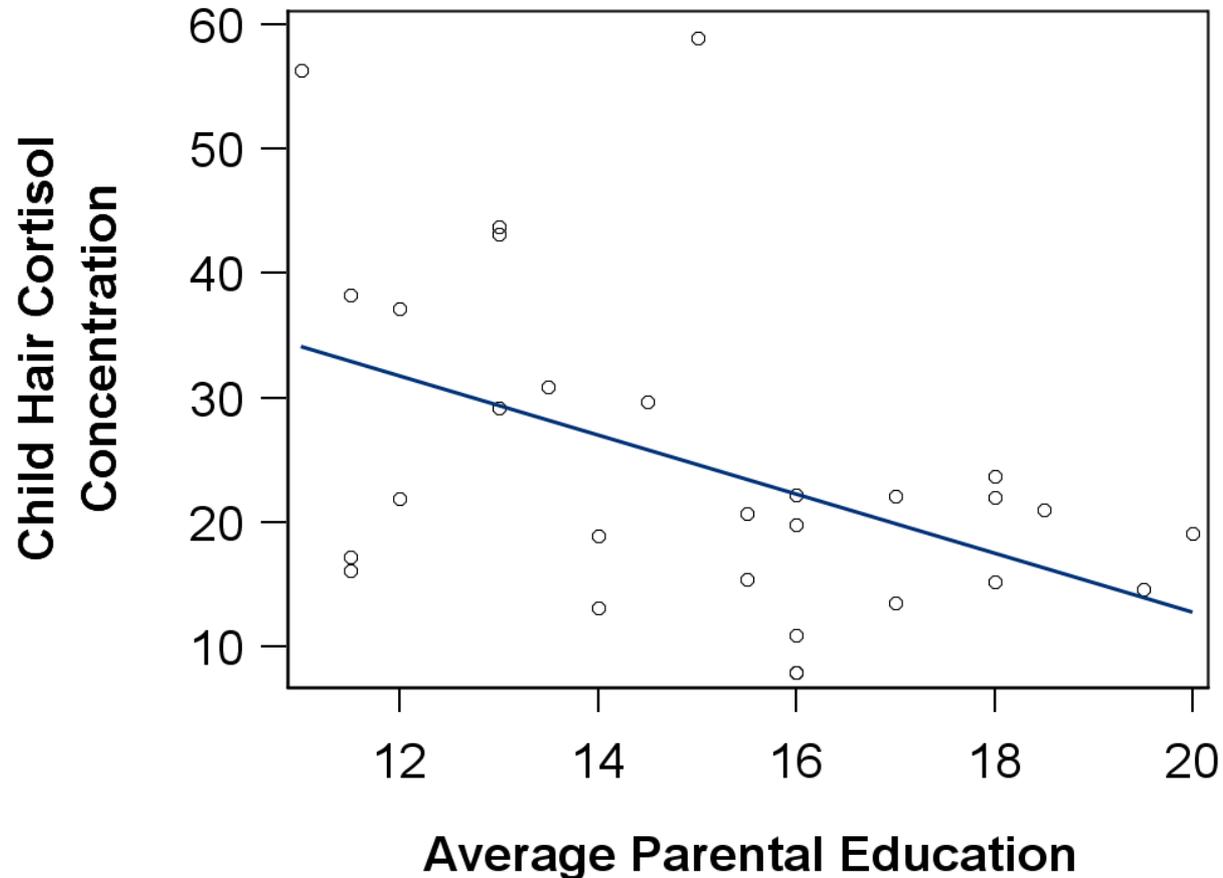


# Does chronic stress explain SES differences in the body and brain?





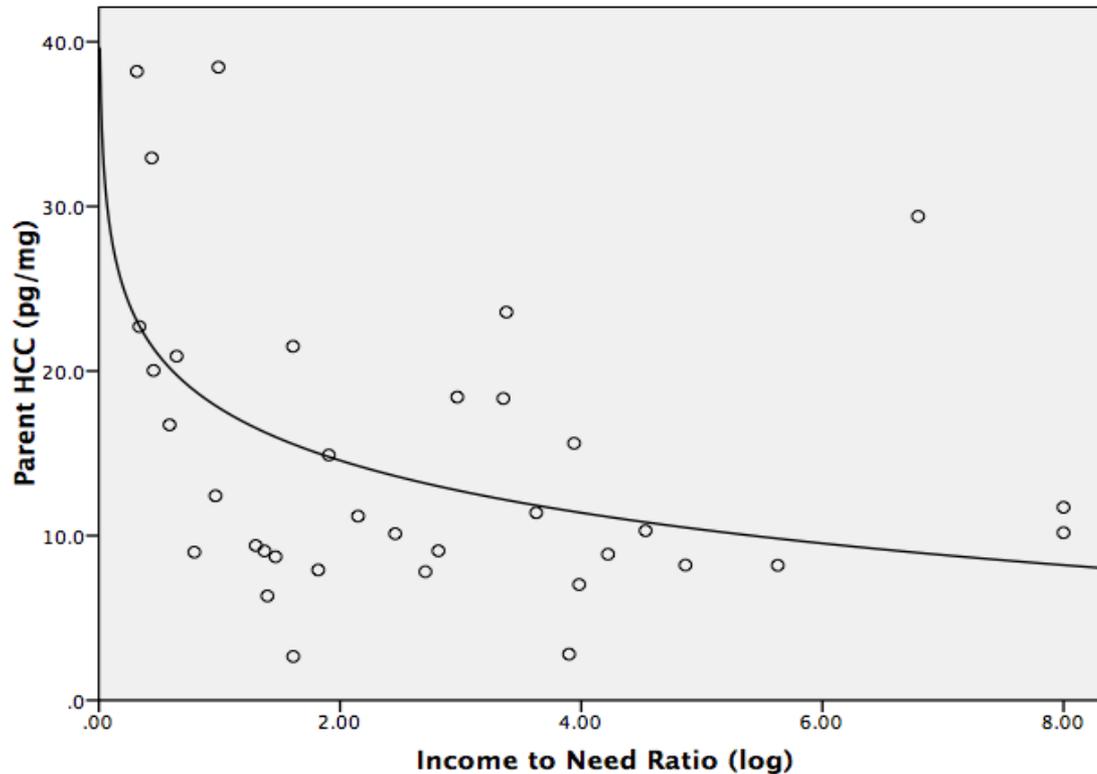
# Higher parent education is associated with reduced child hair cortisol



*Holds when adjusting for parent hair cortisol*

Ursache, Merz et al, 2017,  
*Psychoneuroendocrinology*

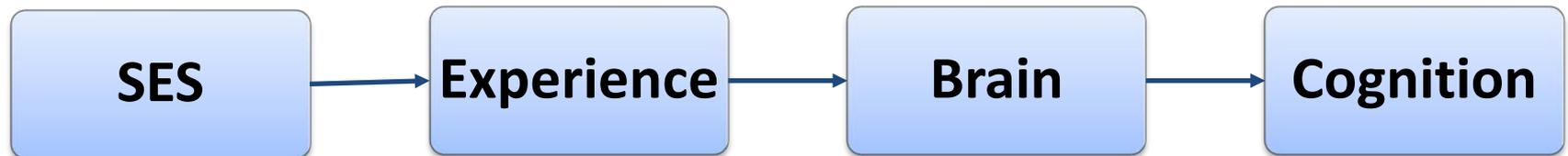
# Higher family income is nonlinearly associated with reduced parent hair cortisol



Ursache, Merz et al, 2017,  
*Psychoneuroendocrinology*

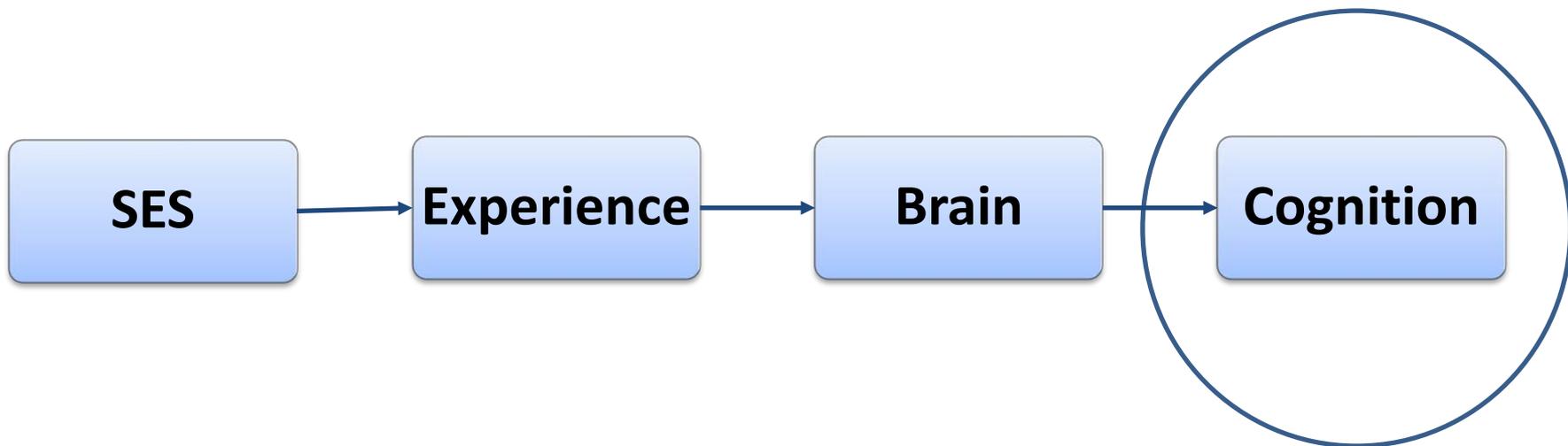
If experience matters, can this work inform interventions?

And what is the right level at which to intervene?



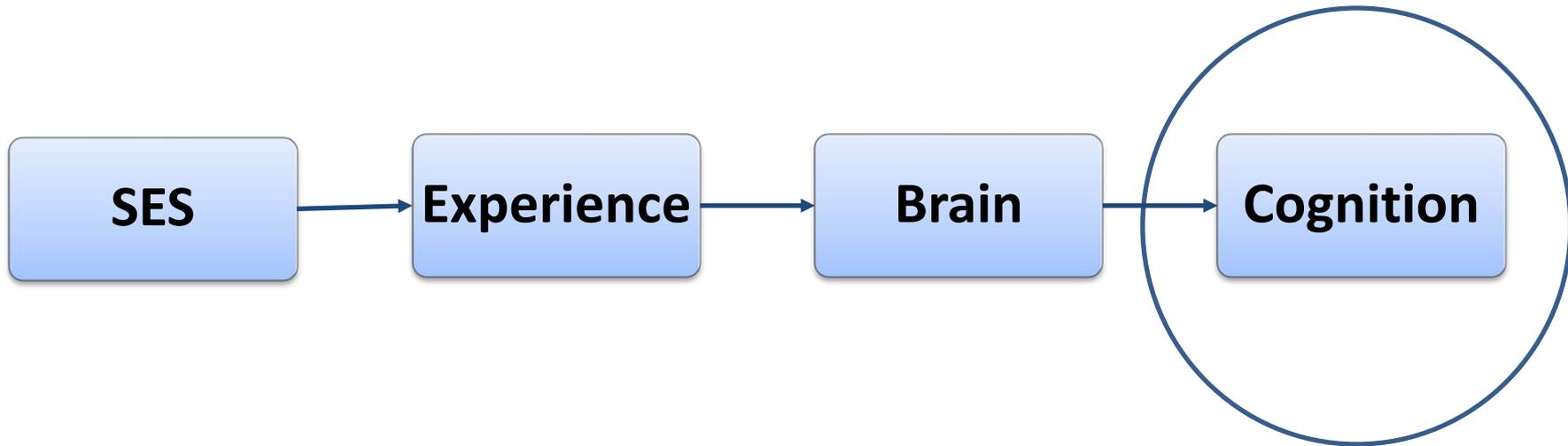
# School-based interventions

- Most common form of intervention addressing SES disparities in achievement

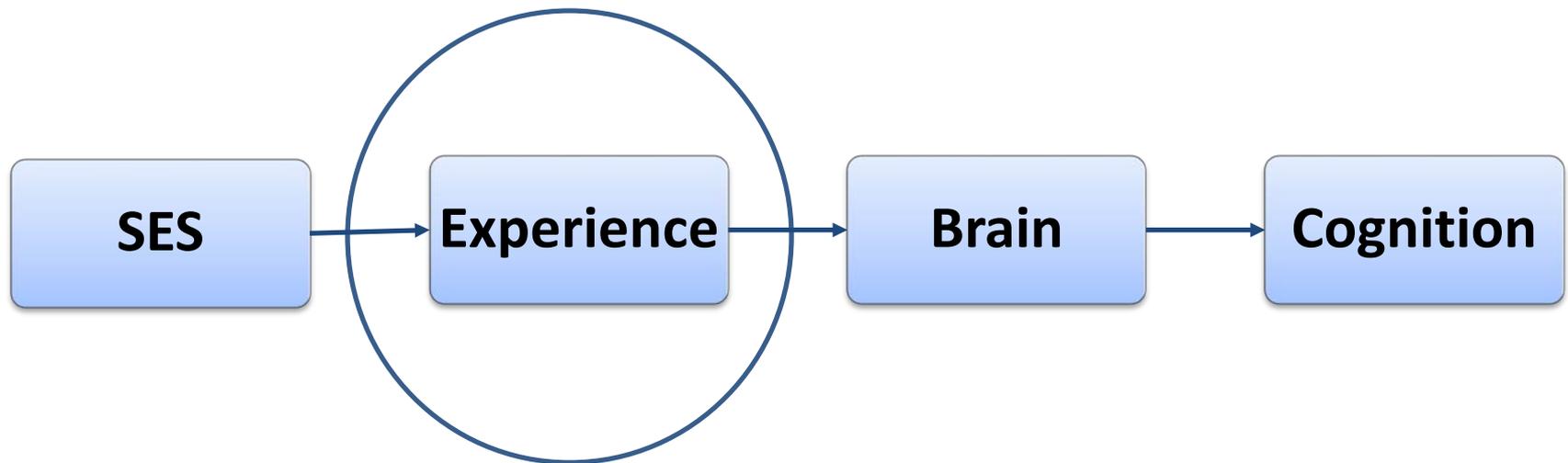


# School-based interventions

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

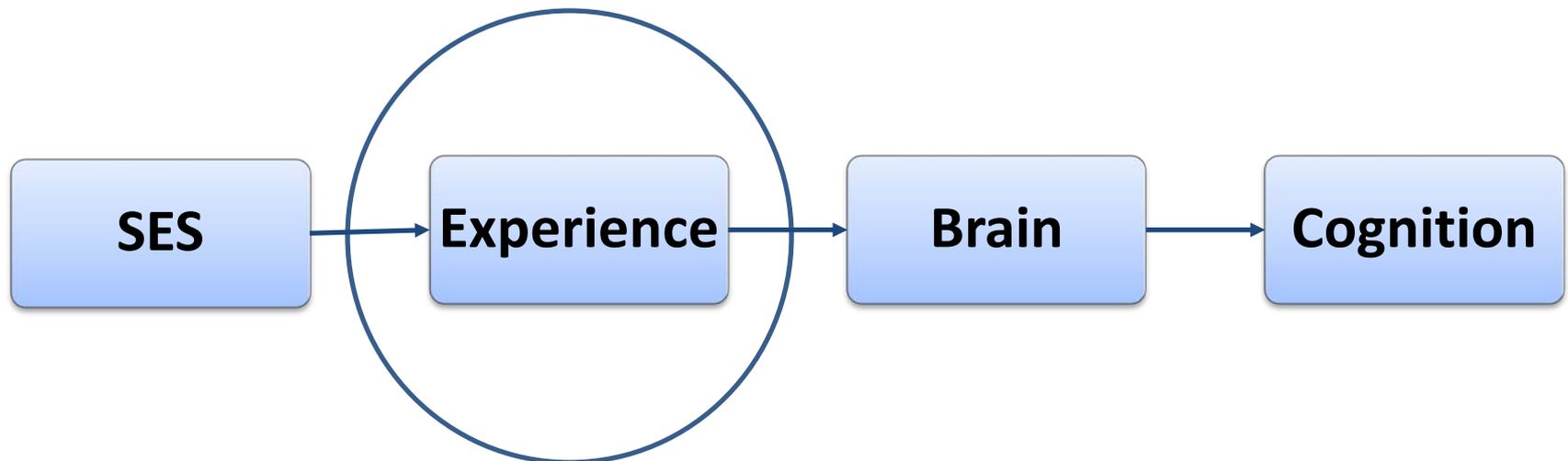


# Changing Experience: Parenting interventions

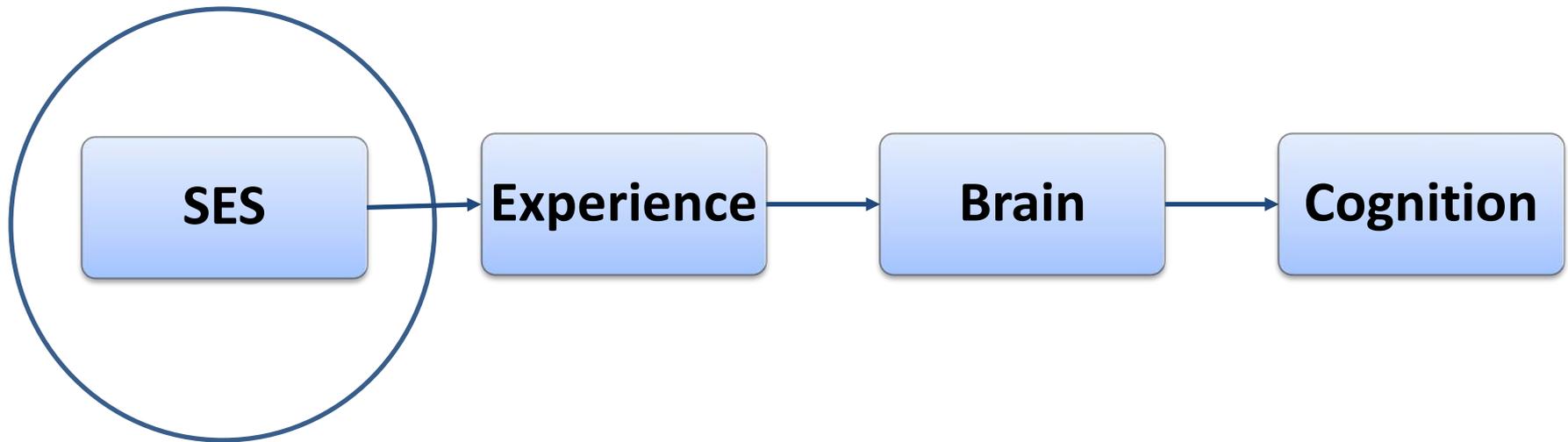


# Changing Experience: Parenting interventions

- 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



# Intervening most distally: Changing SES itself



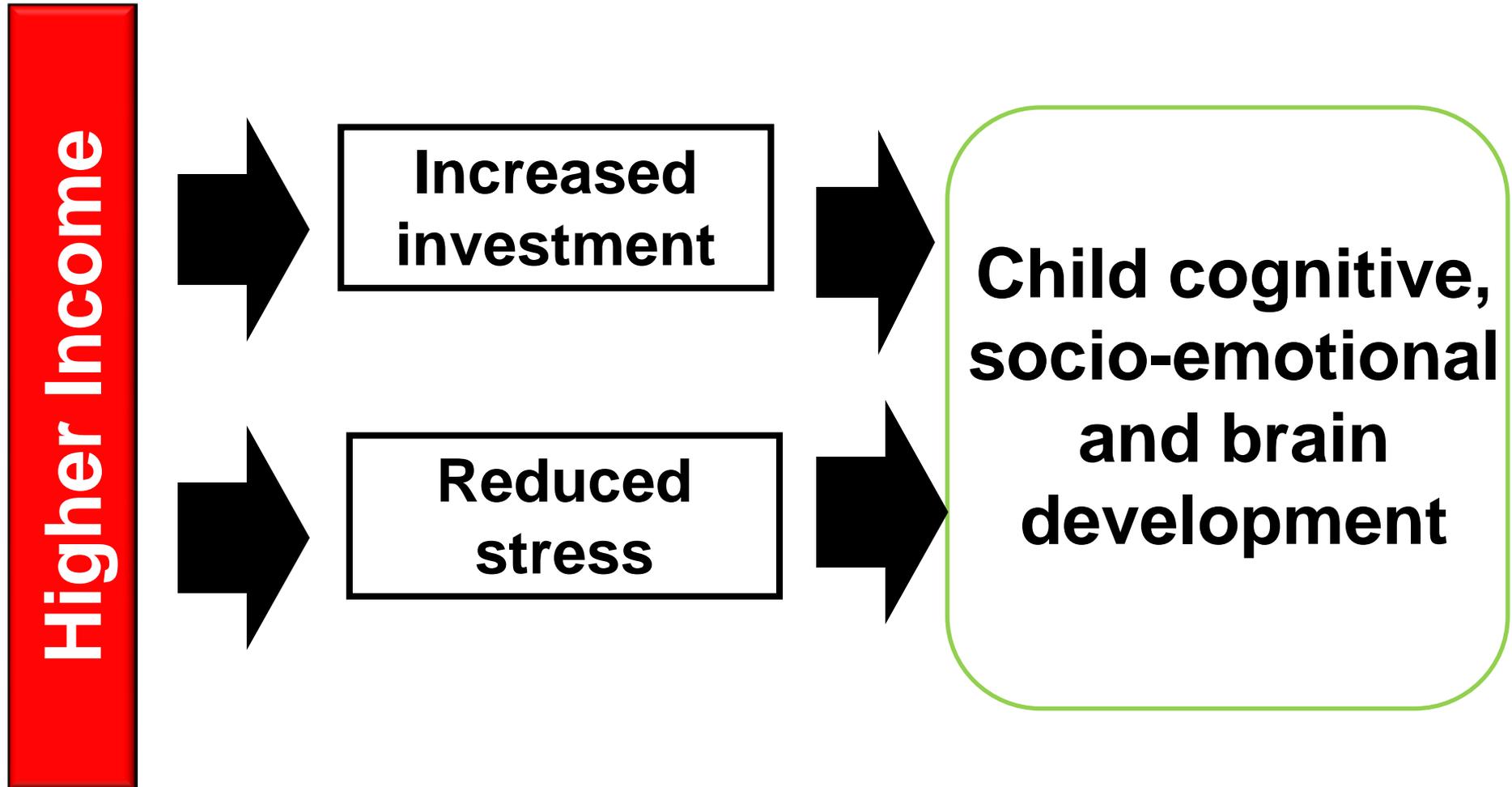
# Income boosts can have big effects

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

# First clinical trial of poverty reduction in early childhood

	<b>National Experiment</b>
<b>Sample</b>	<b>1000 poor mothers (Tentative sites: NYC, New Orleans, Omaha, Minneapolis)</b>
<b>Intervention</b>	<b>\$333/month for 40 months (\$4000/year)</b>
<b>Control</b>	<b>\$20/month for 40 months (\$240/year)</b>
<b>Assignment</b>	<b>Random assignment to control/intervention</b>
<b>Payment</b>	<b>Monthly reload on debit card</b>
<b>Data Collection</b>	<b>Birth, age 1, 2 and 3</b>
<b>Outcomes of interest</b>	<b>Children's cognitive, emotional and brain development; parenting and family functioning</b>

# Developmental theory of change



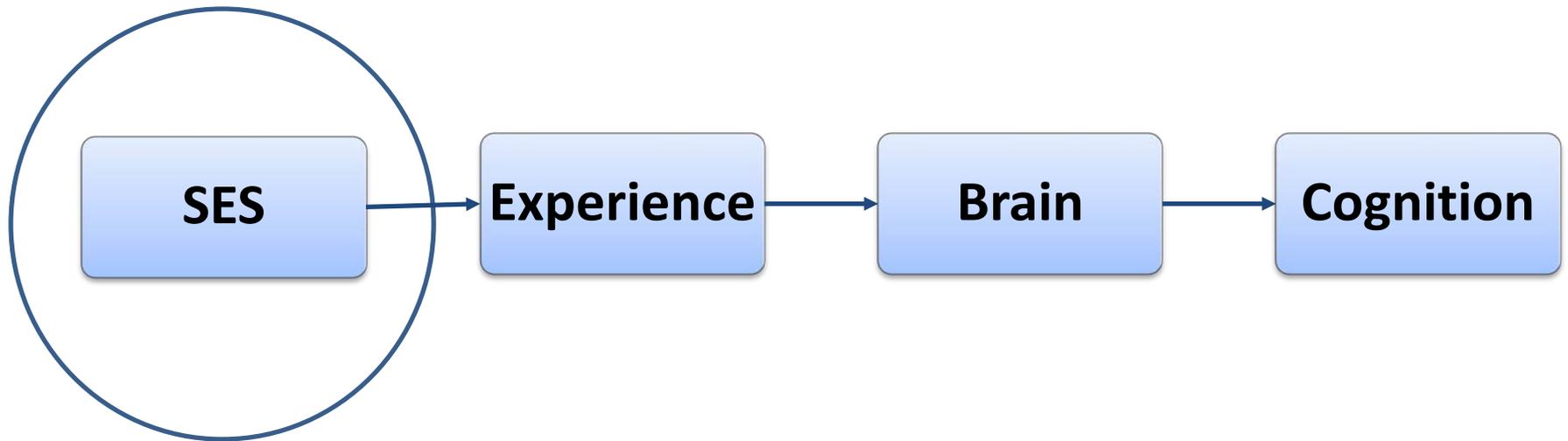
# Highly feasible

- Pilot study with 30 low-income moms in NYC
- 93.3% retention over 12 months
- Very few problems with debit card implementation

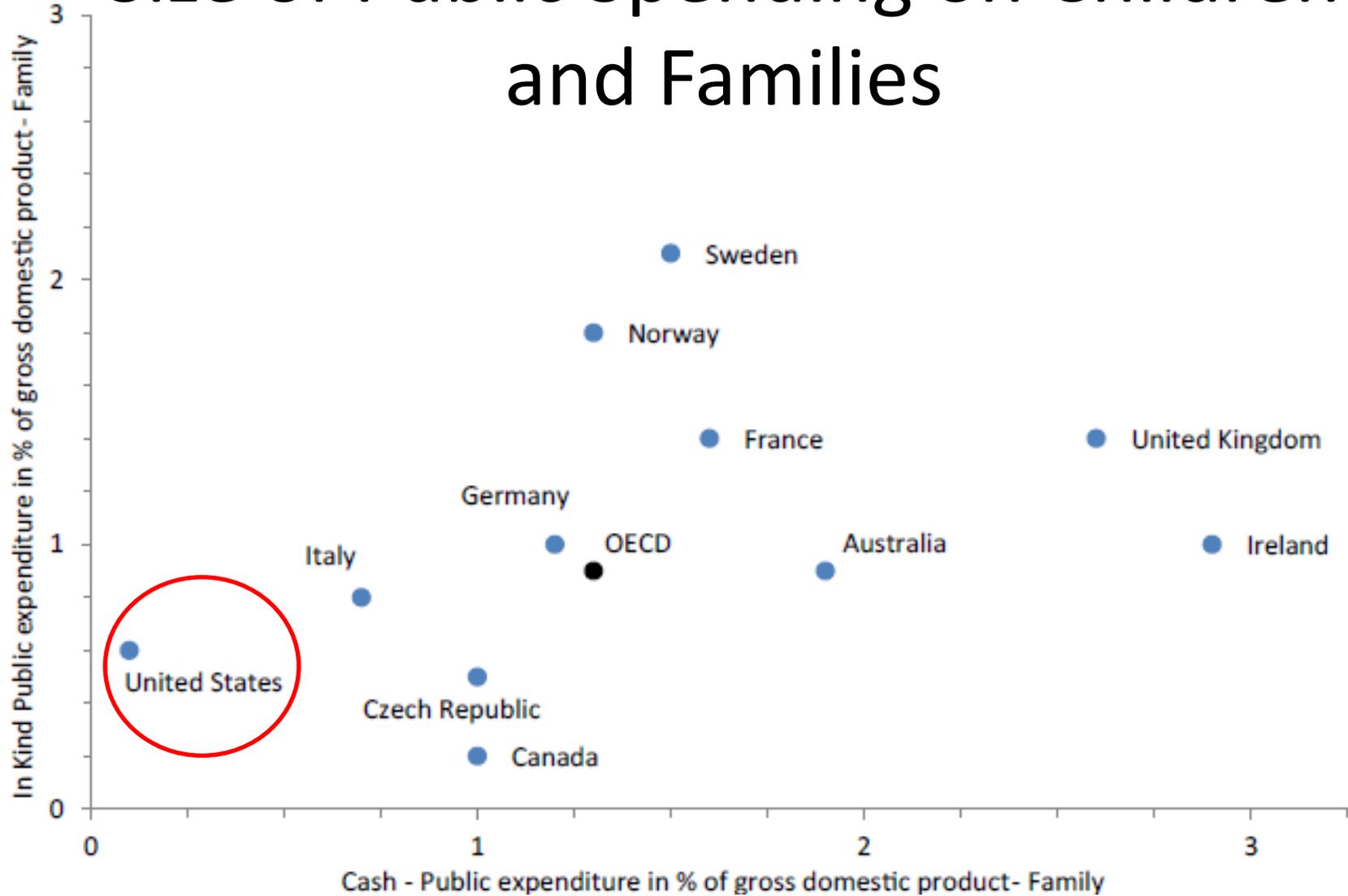
# Intervention group showed preliminary benefits relative to control group

- Small sample size, but patterns suggest
  - Higher center-based child care expenditures
  - More frequent mother-child activities
  - Less household chaos
  - Less parenting stress

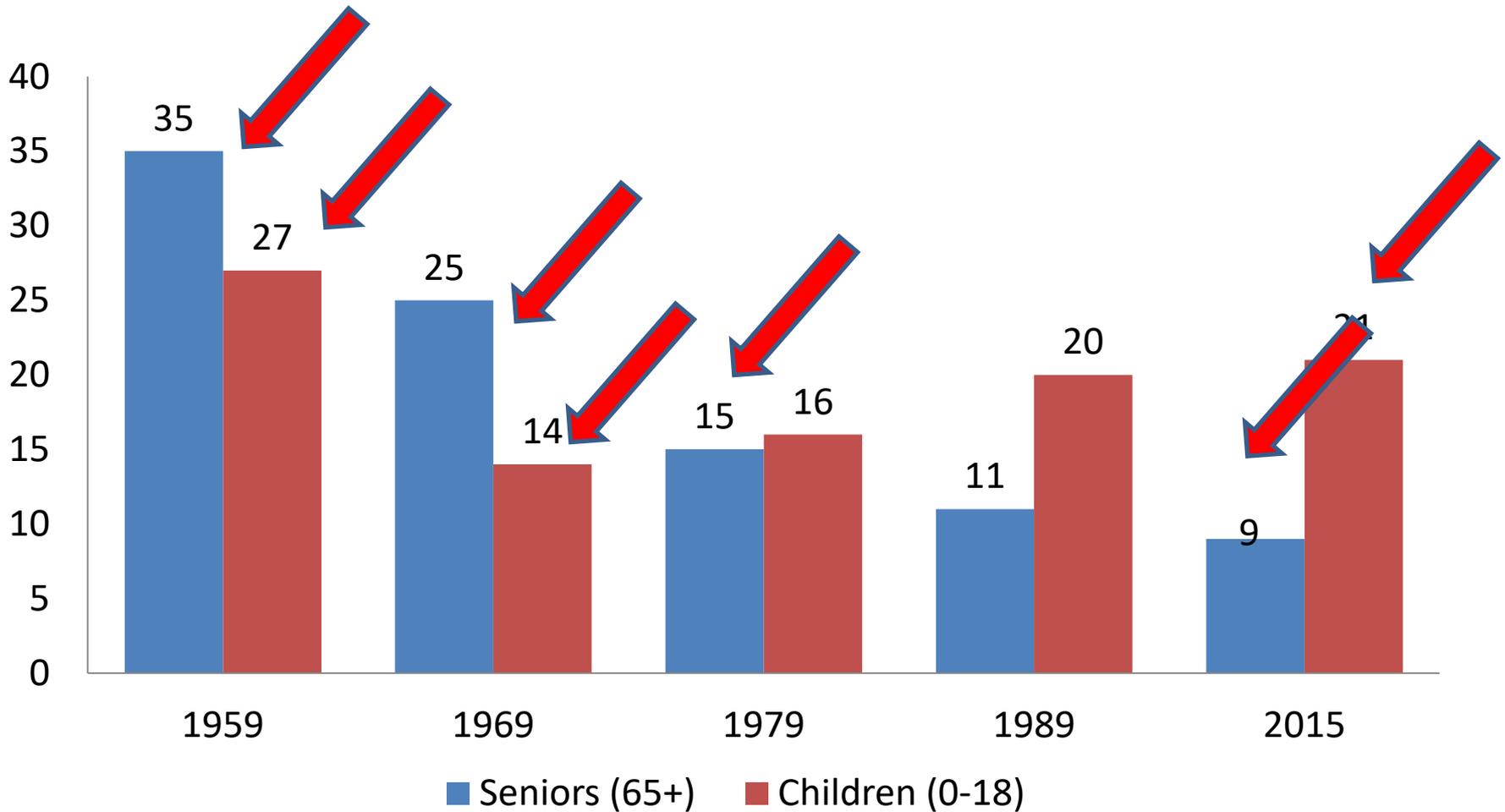
Can boosting family income change children's trajectories?



# Size of Public Spending on Children and Families



# % POVERTY OVER TIME: 1959-2014 SENIORS VS. CHILDREN



Slide courtesy Benard Dreyer, MD  
Sachs JD. *The Price of Civilization*. 2011, Random House,  
NY Chapter 10, pp. 185-208

# 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.*

# Acknowledgements

Neurocognition, Early Experience, and Development (NEED) Lab

[www.columbia.edu/cu/needlab](http://www.columbia.edu/cu/needlab)



@kimberlygnoble



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COLUMBIA UNIVERSITY



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Steven Dow &  
Lynn Schusterman



## Lab Members

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- Chuck Nelson, Ph.D., Harvard
- Elizabeth Sowell, Ph.D., USC

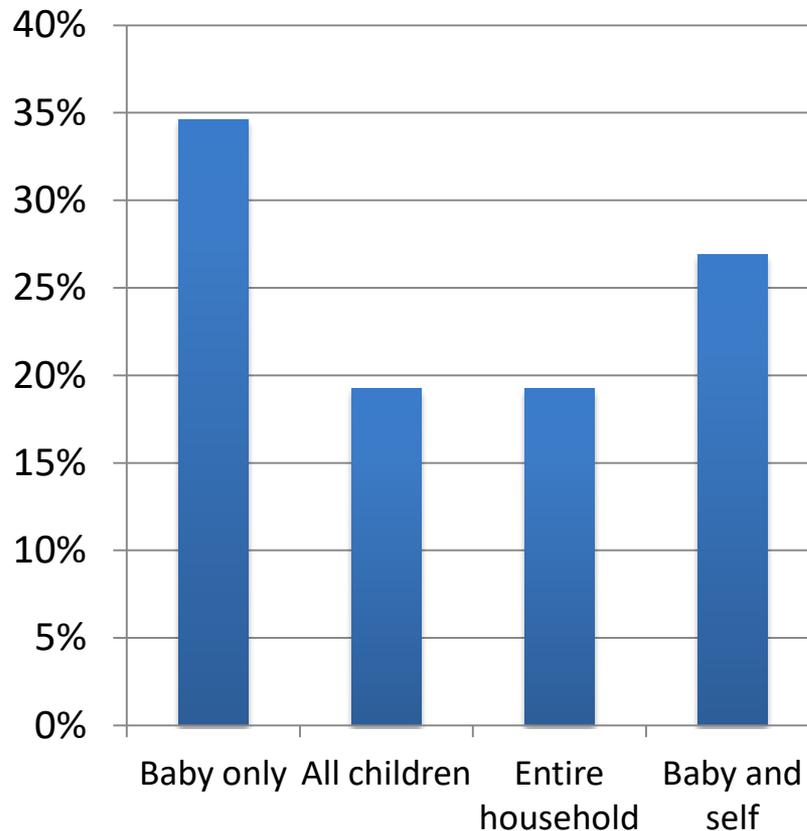
Even in small amounts, money makes a big difference

“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.”

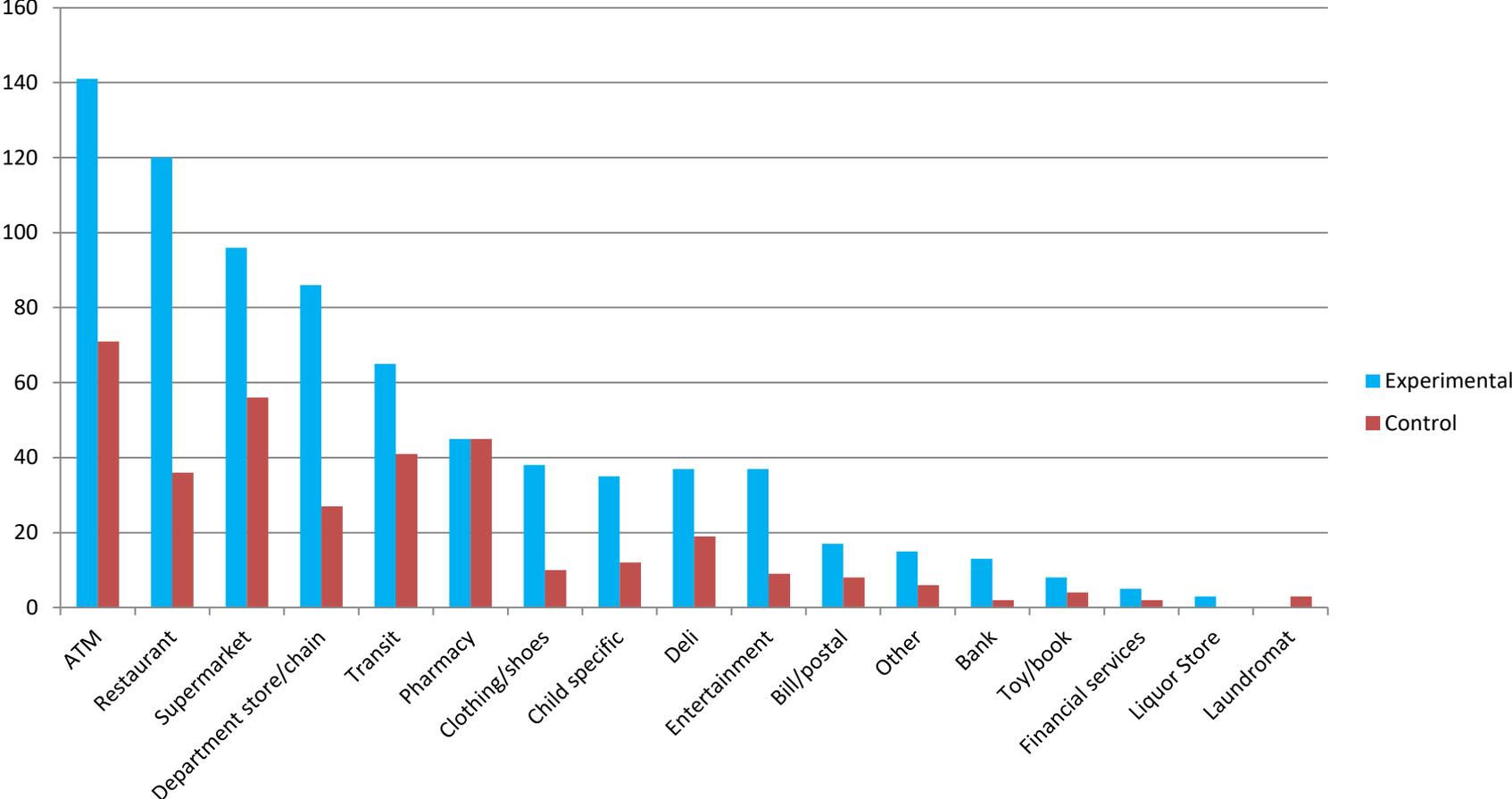
“The money from the card ... really, really helped me out, especially [one] month that we didn't have the food stamps; we didn't have anything at all.”

# Most moms use the card for the baby

**Moms report card payments usually support...**



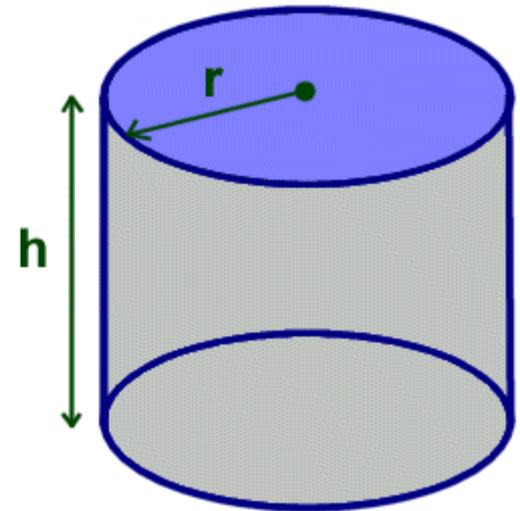
# Debit card use: 1112 transactions over 12 months



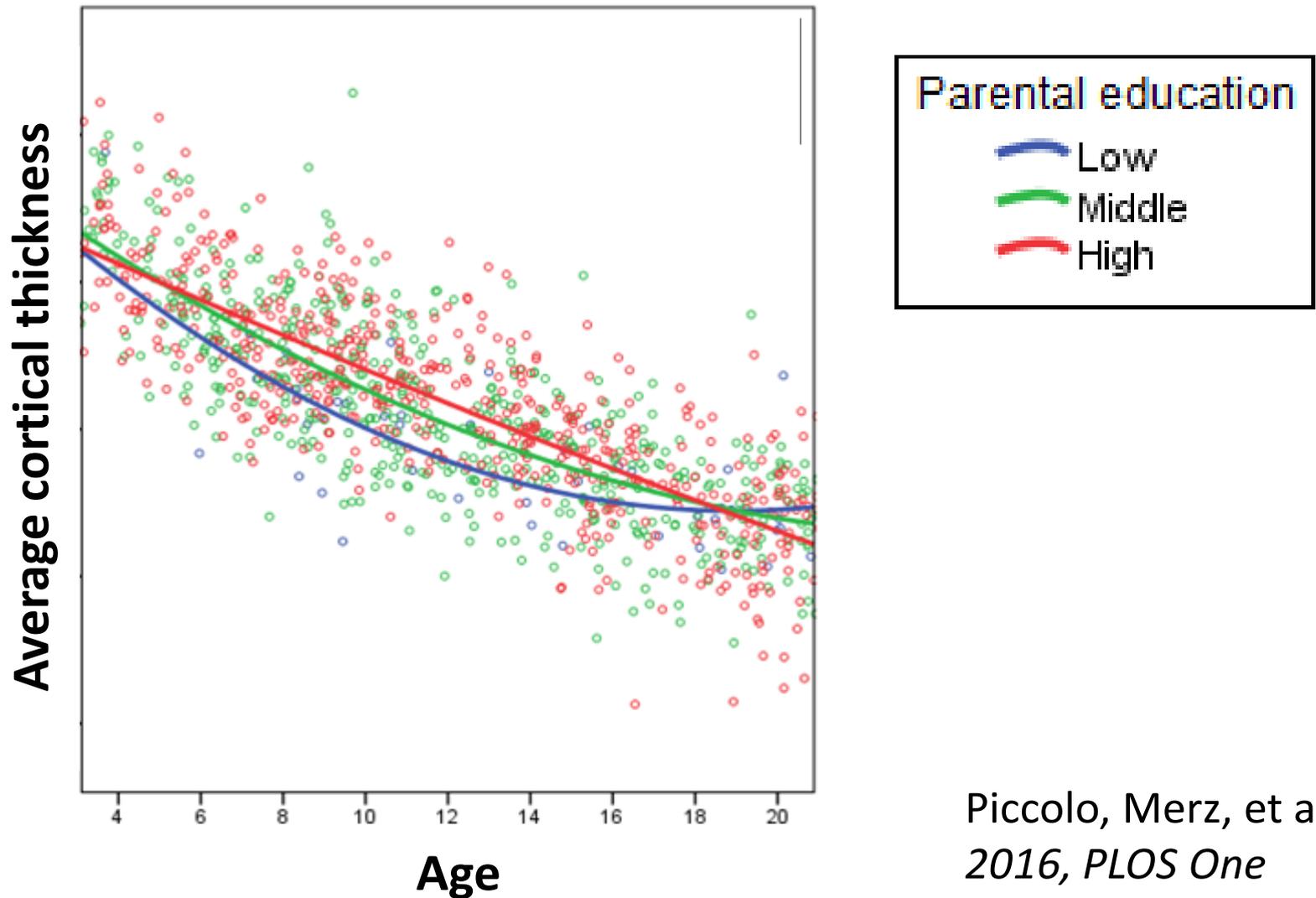
Most studies of brain structure have focused on the volume of the cerebral cortex

- But volume consists of cortical thickness and cortical surface area

**$r$  = radius**  
 **$h$  = height**

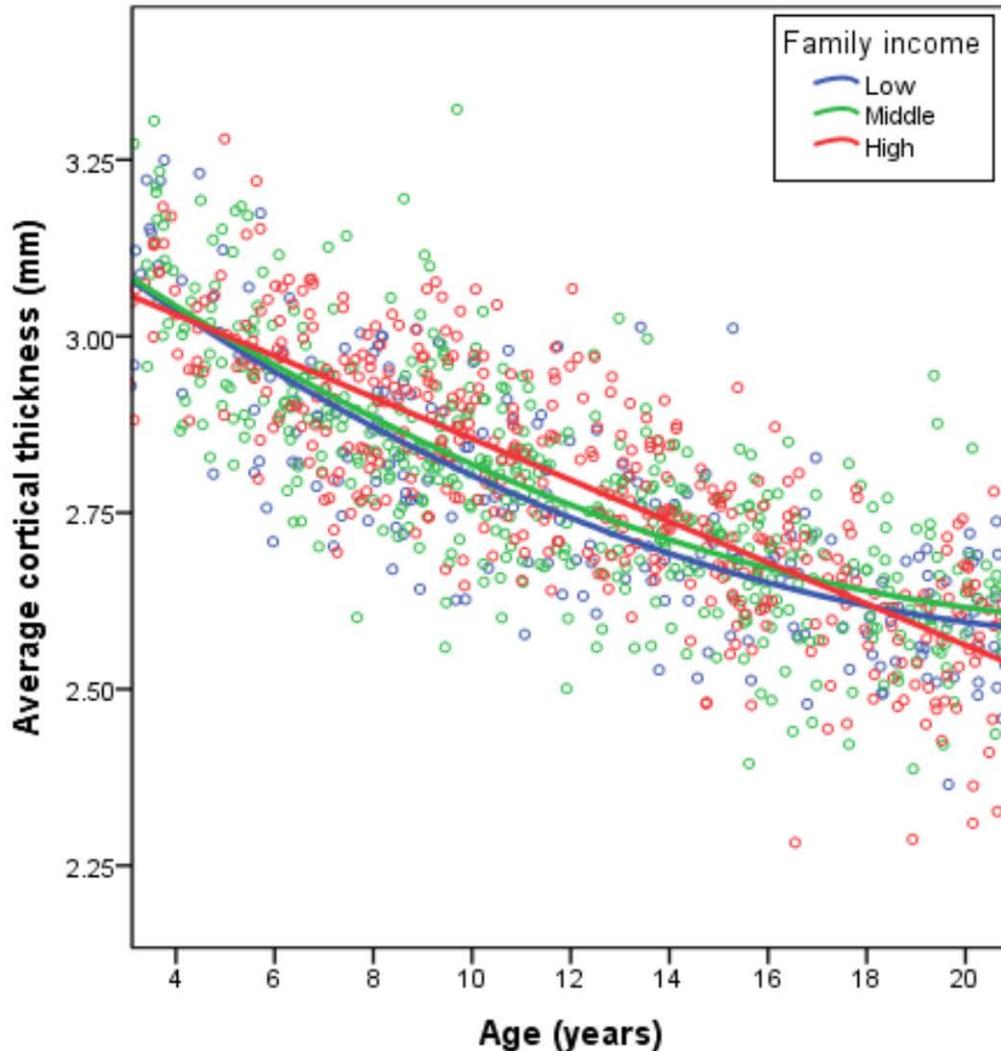


# Age-related differences in cortical thickness vary by parental education



Piccolo, Merz, et al.,  
2016, *PLOS One*

# Age-related differences in cortical thickness vary by family income



Piccolo, Merz et al,  
2016, *PLOS One*