Environmental Influences on the Neural Basis of Language & Reading Development

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Socioeconomic Status (SES)

- "An individual's access to **economic and social resources**, as well as the benefits and **social standing** that come from these resources. Brito & Noble 2014

- SES is often measured as a combination of **educational attainment**, **income**, and/or **occupation**. Ensminger & Fothergill, 2003
  - Though correlated, these 3 factors exert unique influences on development. Duncan & Magnusen 2012

- SES indexes a number of correlated factors:
  - Chronic/toxic stress
  - Violence exposure
  - Nutrition
  - Access to health care
  - Exposure to toxins/pollutants
  - Educational resources
  - Parental/caregiver availability

The SES Achievement Gaps

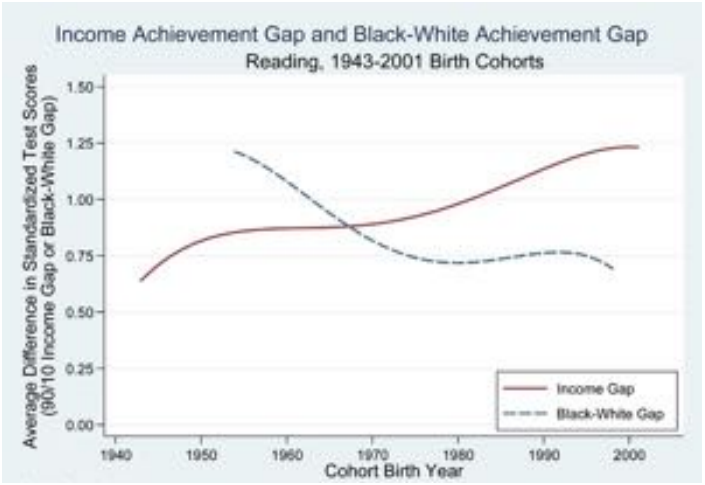
- SES is a strong predictor of academic achievement and cognitive skill
  - Gaps start in infancy e.g., Hart & Risley, 1995; Fernald, Marchman, & Weisleder 2013; Bettancourt et al., 2015
  - Certain achievement gaps can widen with age e.g., Lee & Burkam, 2002

"Vocabulary Gap" ☞

Hart & Risley, 1995

- The vocabulary gap in kindergarten fully explains the reading gap in later elementary school. Durham, 2007

- "The income achievement gap is now nearly twice as large as the black-white achievement gap." Reardon, 2011

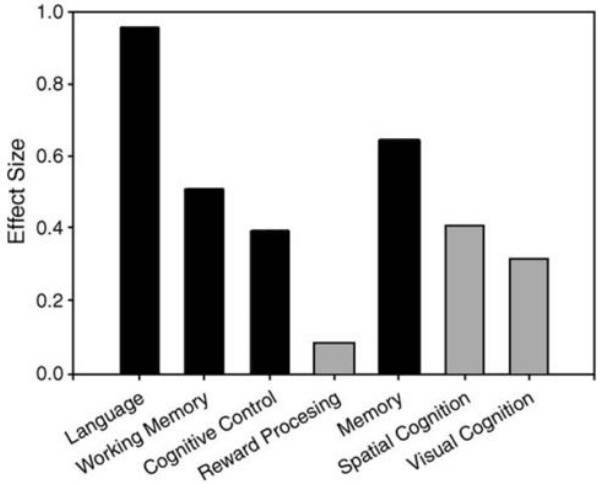


Reardon, 2011

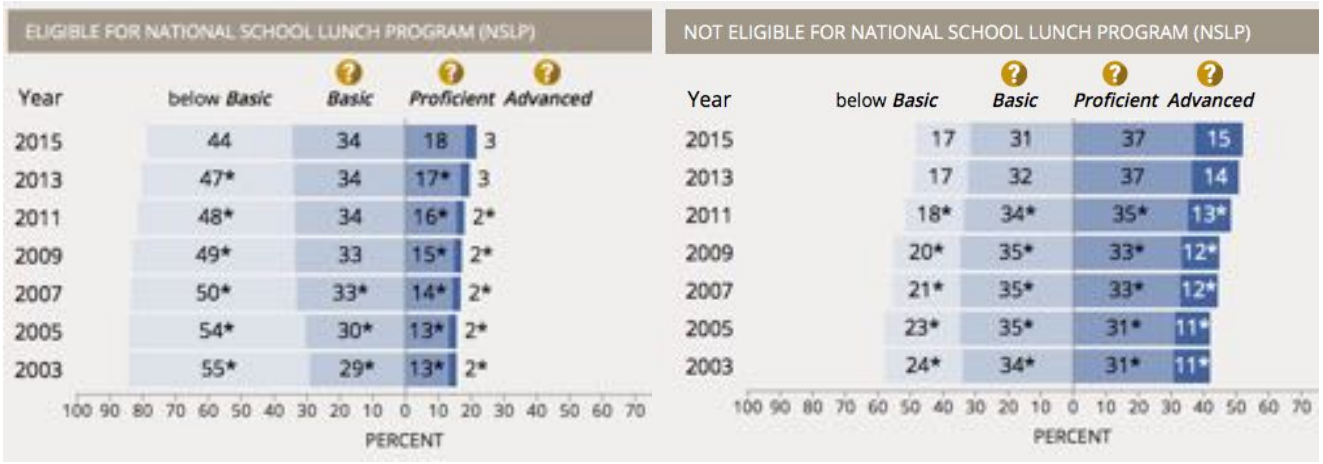
SES is associated with reading skills

- SES is more strongly related to language and literacy skills than other neurocognitive domains. Farah et al., 2006; Noble, et al., 2007; Jednorog et al., 2012

- Low-income students have a disproportionately higher rate of RD diagnosis Shifrer et al., 2011; Peterson & Pennington, 2015 and are 2.5 times more likely to read at below proficient levels. USDOE 2015

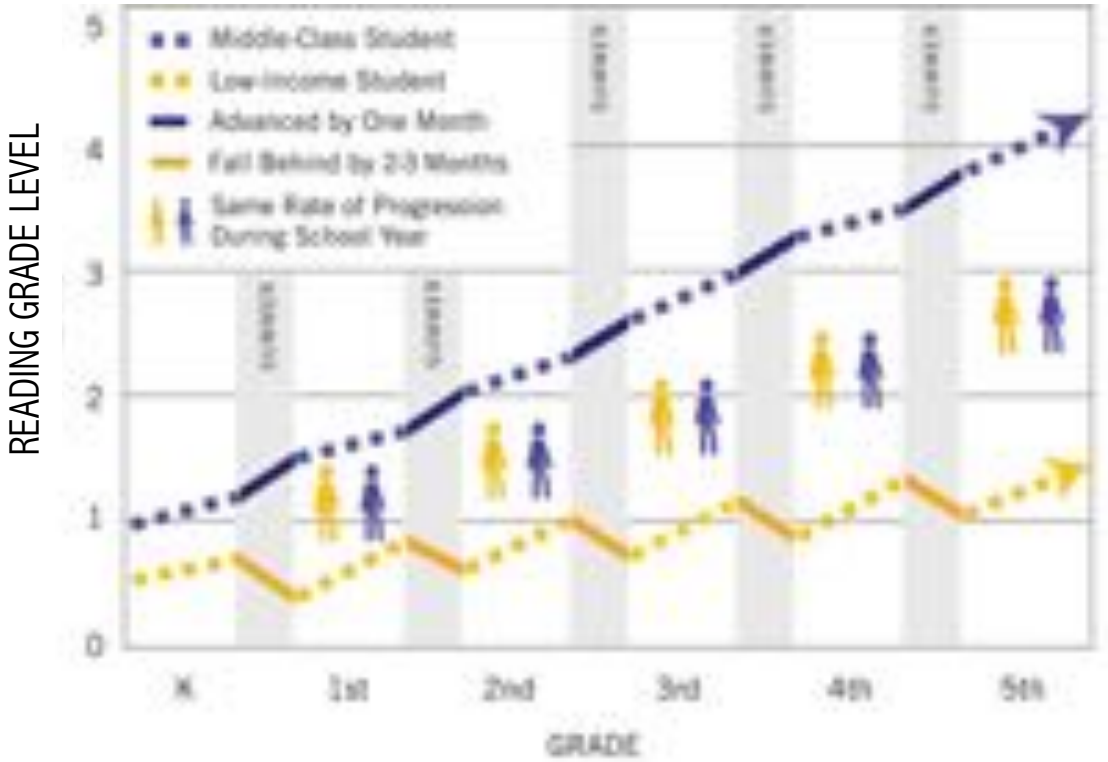


Farah et al., 2006



The Summer Slide

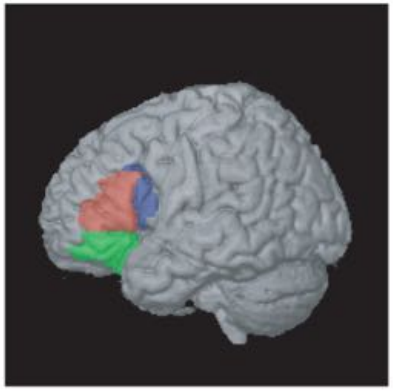
- While higher SES children make reading gains in the summer, lower SES child decline in ability, widening the gap.

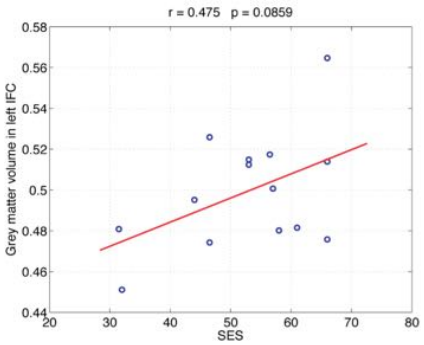


- By ninth grade, more than half of the income achievement gap is explained by unequal access to summer learning opportunities during the elementary school years. Alexander et al., 2007

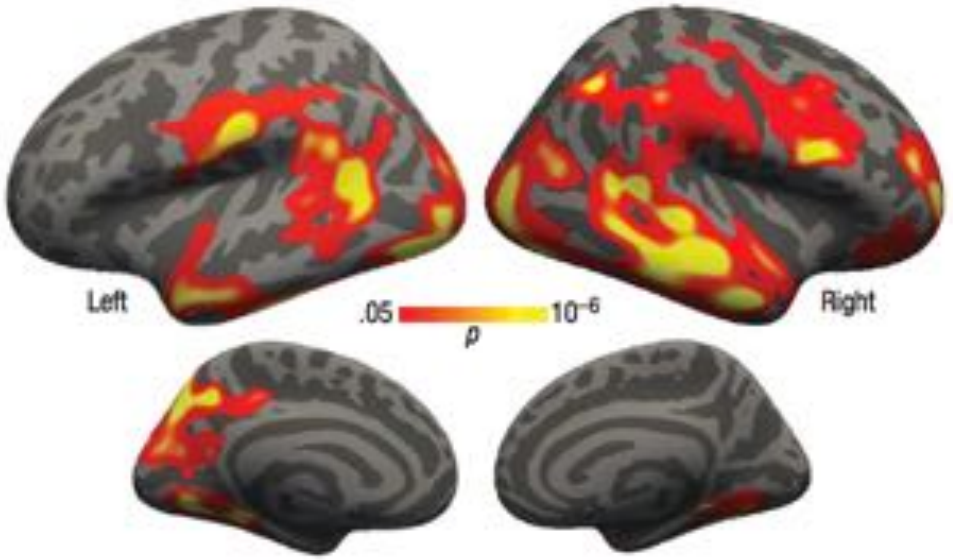
SES and the brain

SES is positively correlated with cortical thickness and volume, especially in canonical language and reading regions. Brito & Noble, 2014



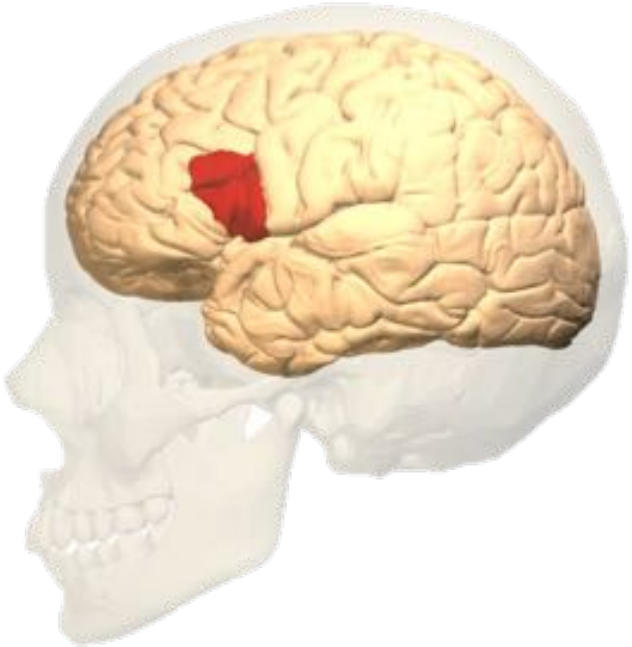


Raizada et al., 2008

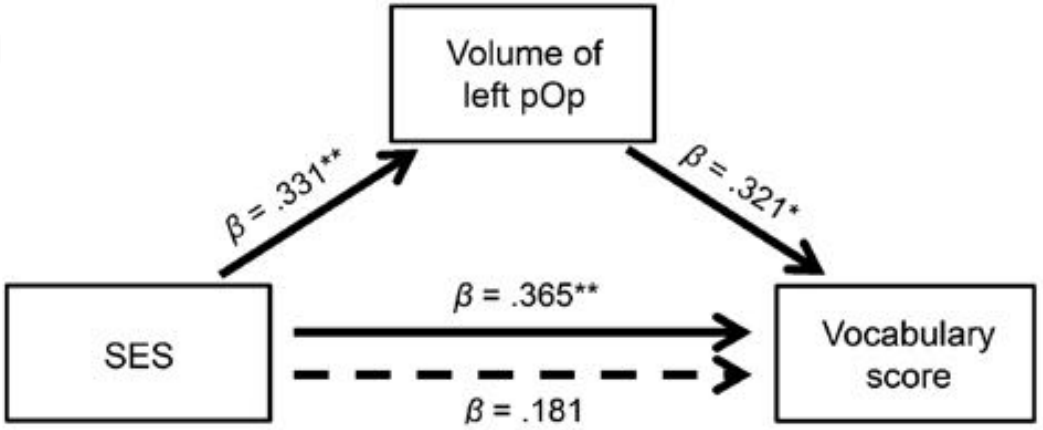


Mackey et al., 2015

Structure of Broca's area underlies the "Vocabulary Gap"

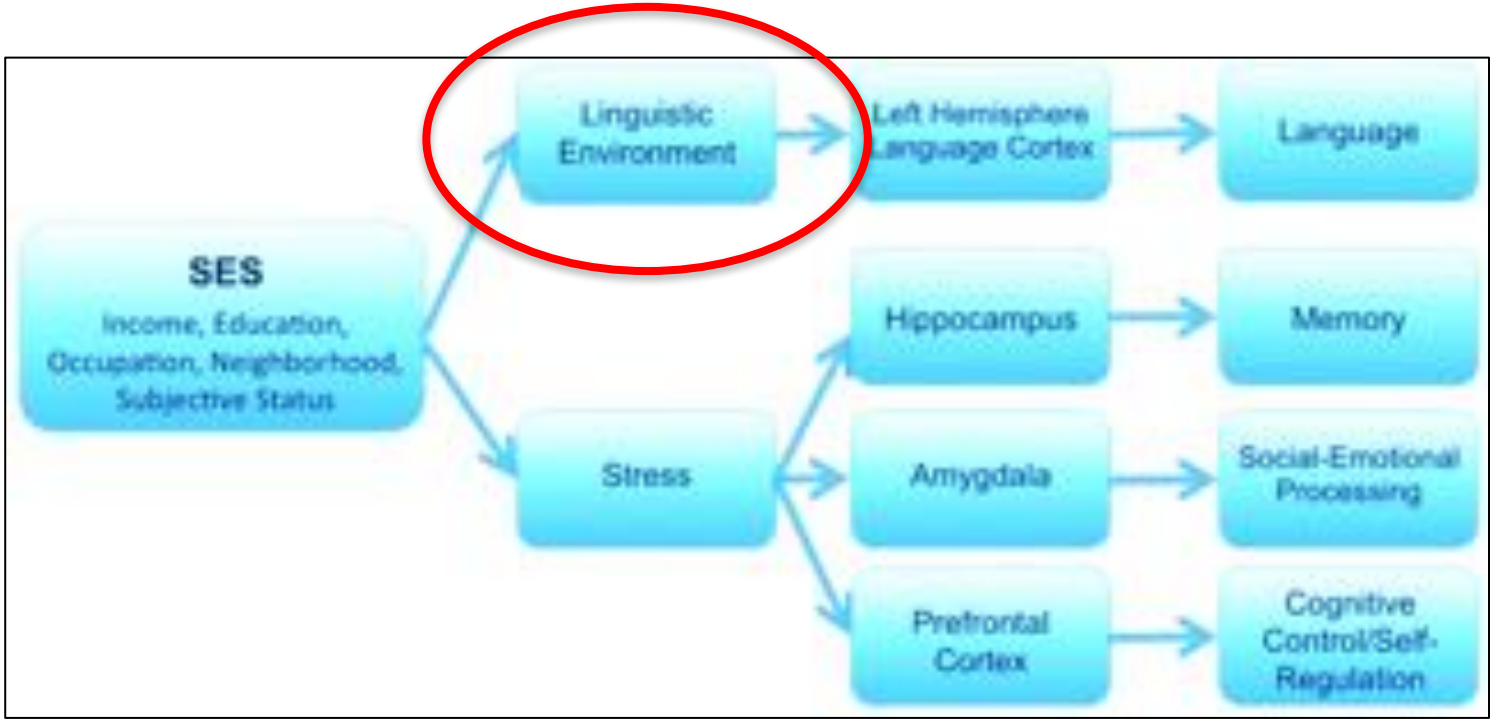


Pars Opercularis



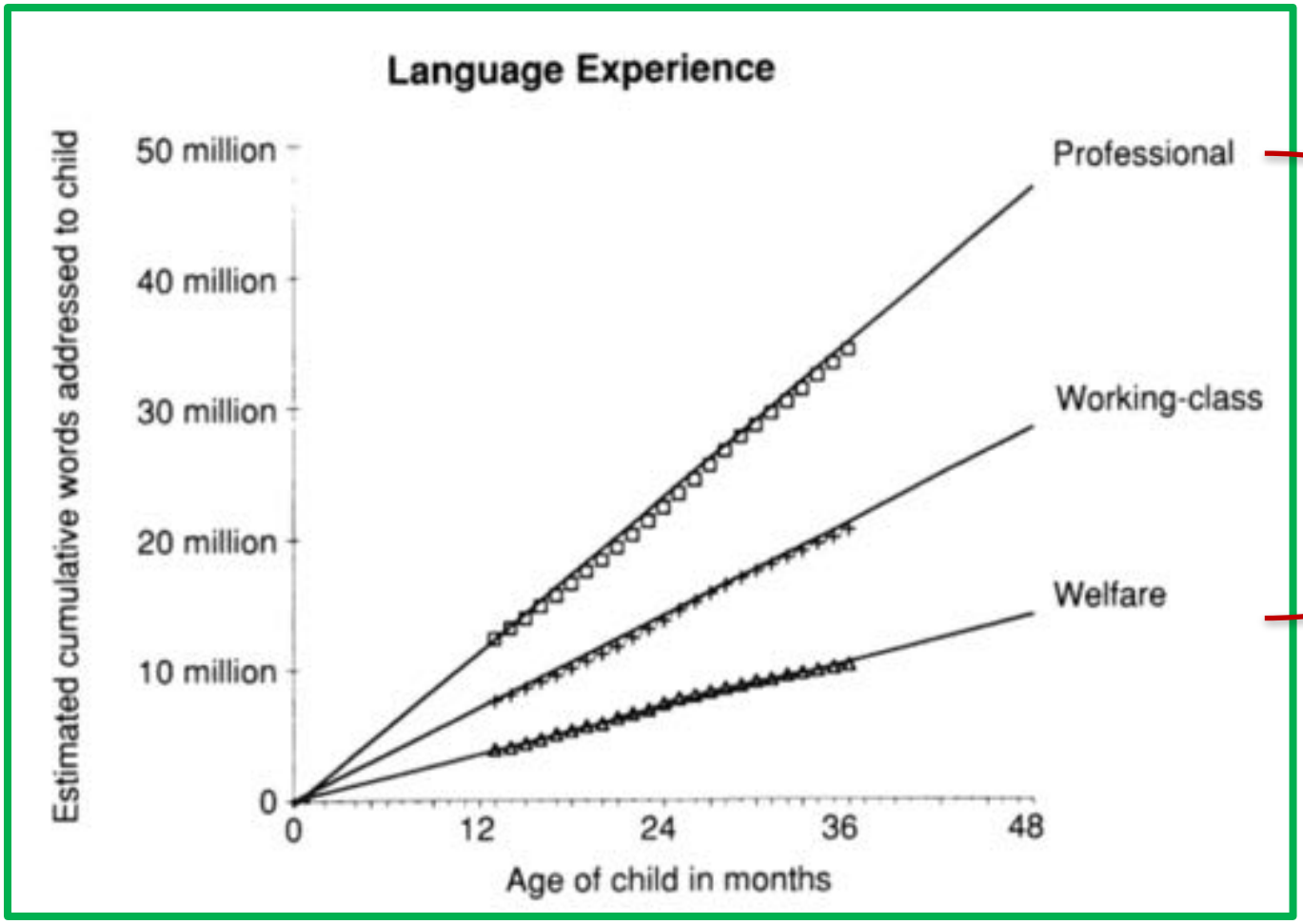
Romeo et al., *Cerebral Cortex*, 2017

(Potentially) Causal Pathways



Brito & Noble, 2014
(also Perkins, Finegood, & Swain, 2013;
Noble, Houston, Kan, & Sowell, 2012)

The "30 Million Word Gap"



Hart & Risley, 1995

Within-SES Variability

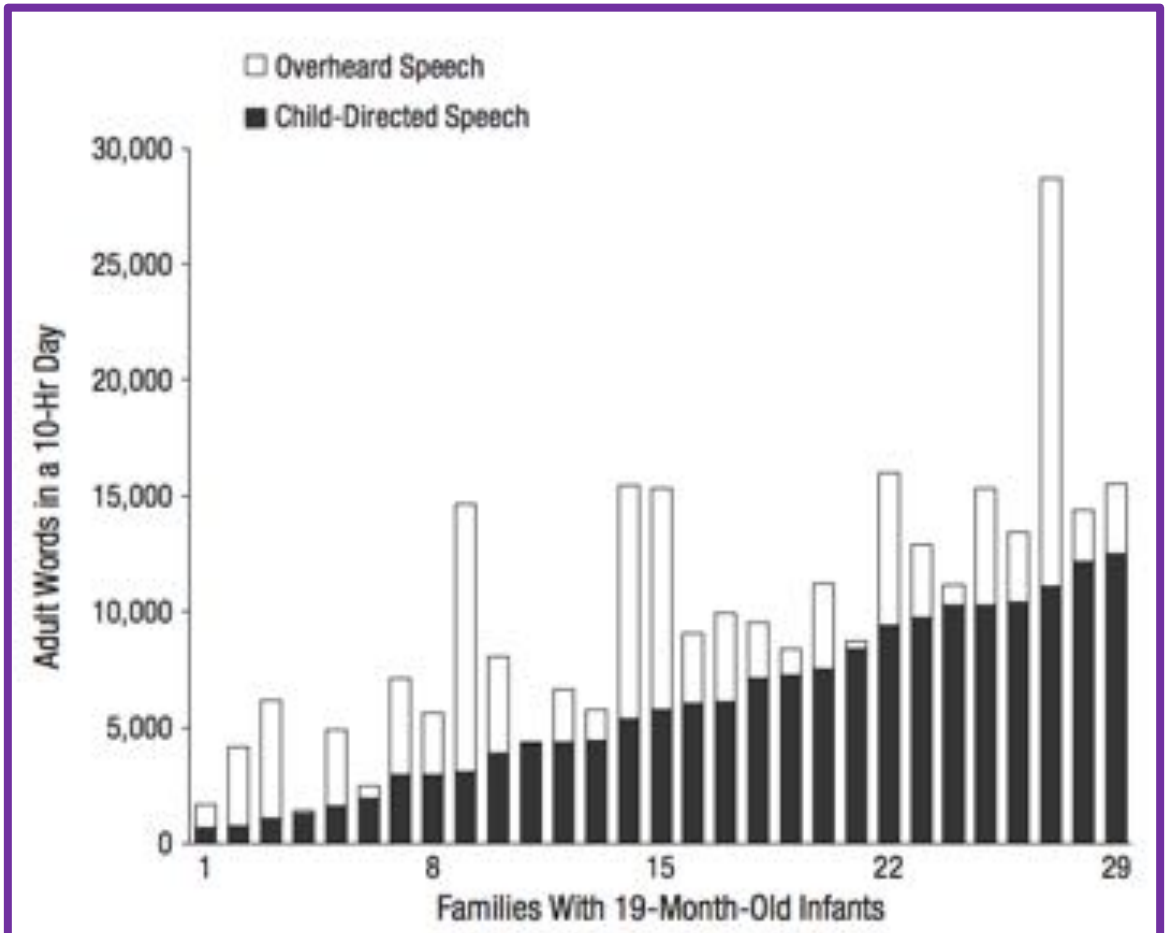
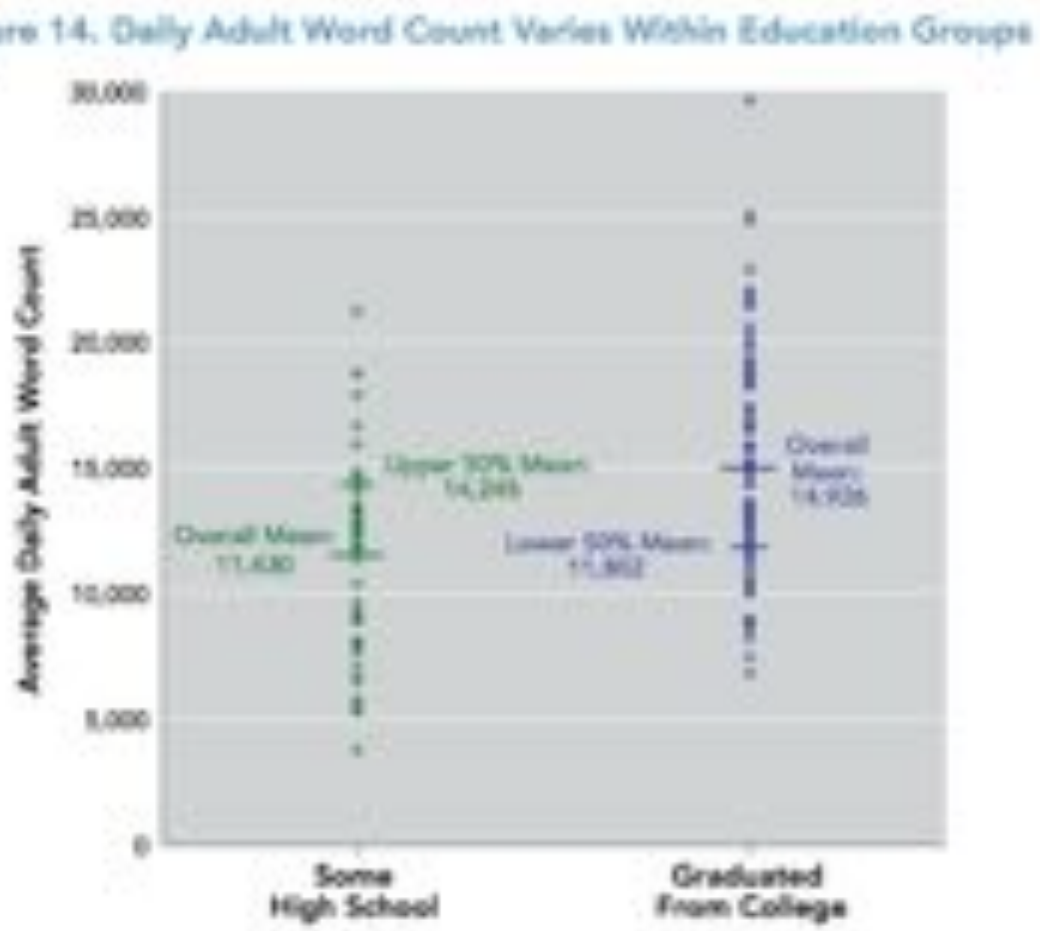


Fig. 1. Mean number of words that infants heard adults speak in a typical day at home for each family and each type of speech.

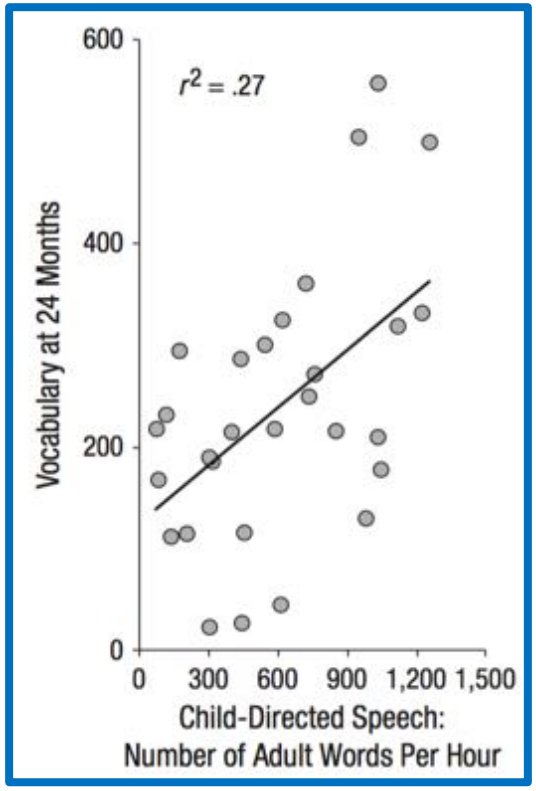
Weisleder & Fernald, 2013

Within-SES Variability



LENA Natural Language Study, 2008

Language Input ☞ Language Output

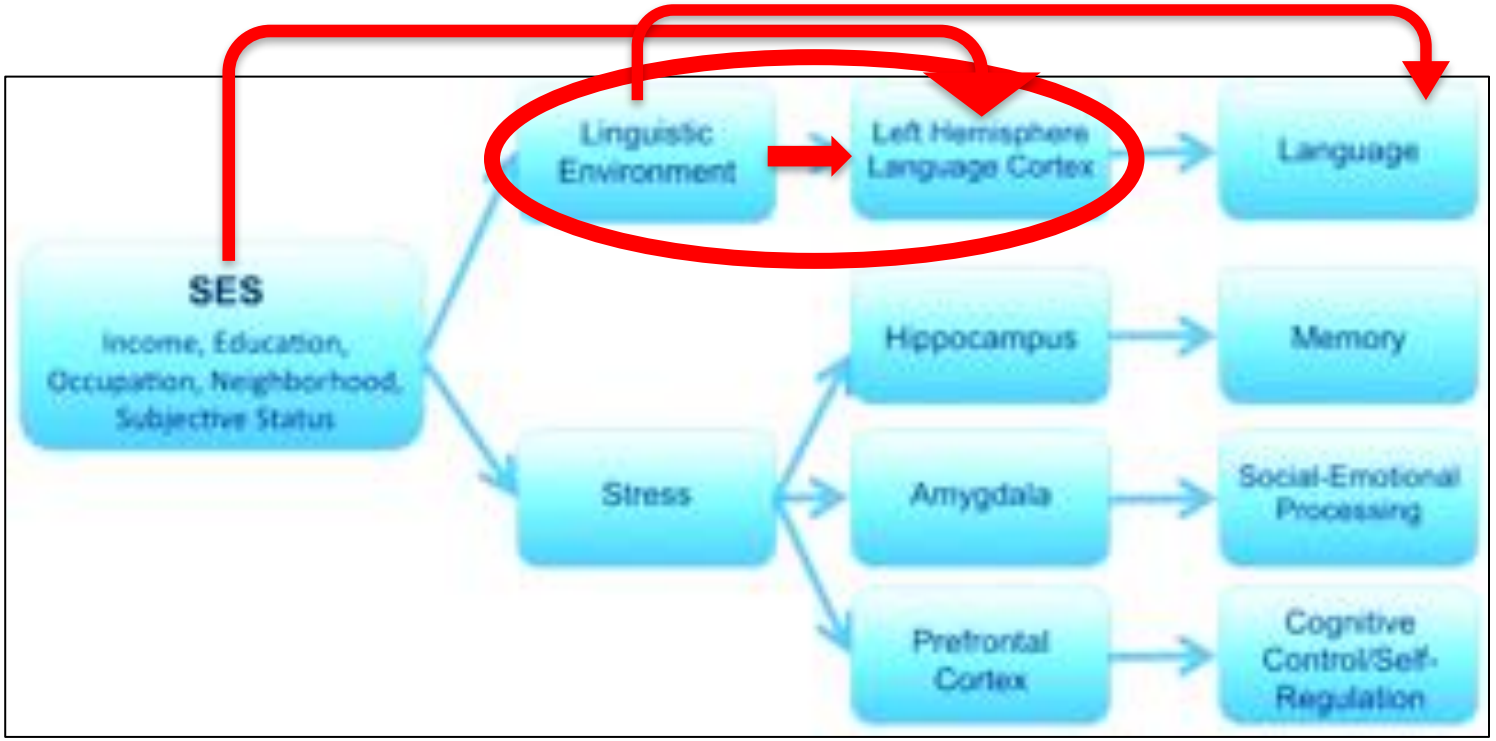


Weisleder & Fernald, 2013

	PPVT		
	30 months (n = 48)	42 months (n = 50)	54 months (n = 48)
Word types	0.06	0.43**	−0.03
Rare word types	−0.00	0.35*	−0.11
Narrative utterances	0.02	0.02	0.34*
Pretend utterances	0.01	0.02	−0.01
Explanation utterances	0.09	−0.02	0.29*

Rowe, 2012

(Potentially) Causal Pathways

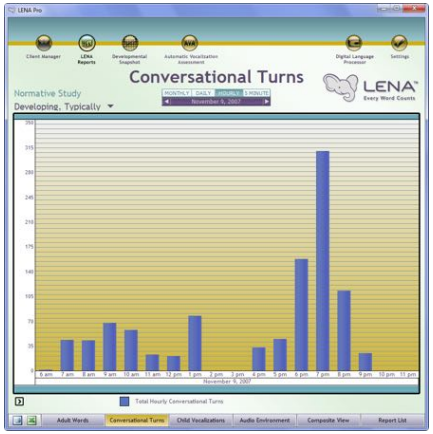


Brito & Noble, 2014
(also Perkins, Finegood, & Swain, 2013;
Noble, Houston, Kan, & Sowell, 2012)

Measuring the Language Environment

- Small, child-worn recorder than can hold a whole day's worth of audio (16 hrs)
- Software automatically analyzes recordings and determines:
  - How many "adult words" the child heard
  - How many "child vocalizations" the child said
  - How many "conversational turns" occurred between the child and any adult

"LENA"



LENA Demo

http://lenafoundation.screenstepslive.com/s/support/m/18913/l/290951-video-introduction-to-the-lena-system

Methods

- Participants (n = 58)
  - Children ages 4-6 years, in pre-K or Kindergarten
  - Native English, no diagnoses/history of lang. impairment
  - Diverse SES (combined parental education and income)

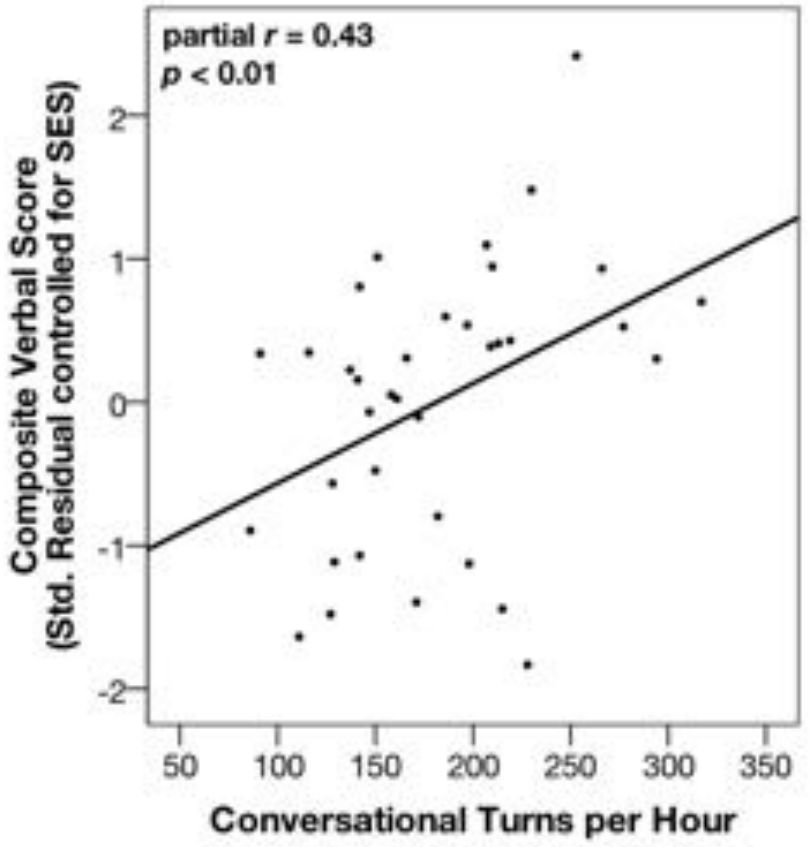
- Standardized language/cognition assessments
  - Receptive Vocabulary (PPVT-4)
  - Receptive/Expressive Language generally (CELF-5)
    - Composite Language Score = avg. standard scores PPVT-4 & CELF-5
  - Non-verbal cognition (WPPSI-IV)

- (f)MRI
  - Structural MRI (n = 54)
  - Task (n = 36): listening to simple stories vs. backwards speech
    = higher level language comprehension

- Home Recording
  - 2 complete weekend days of LENA

Photos from Nova's "School of the Future"

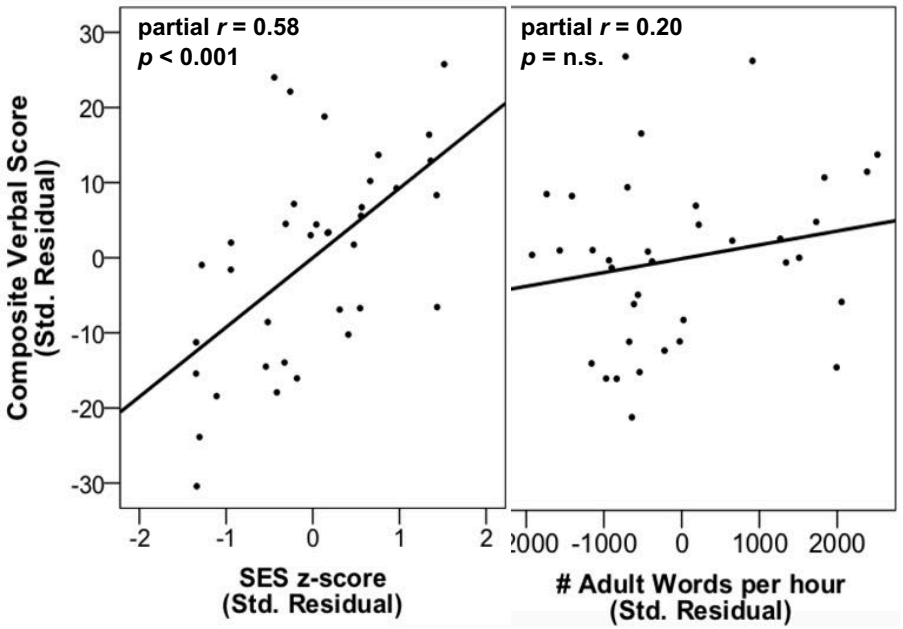
Number of Conversational Turns explain Verbal Scores **independent of SES**

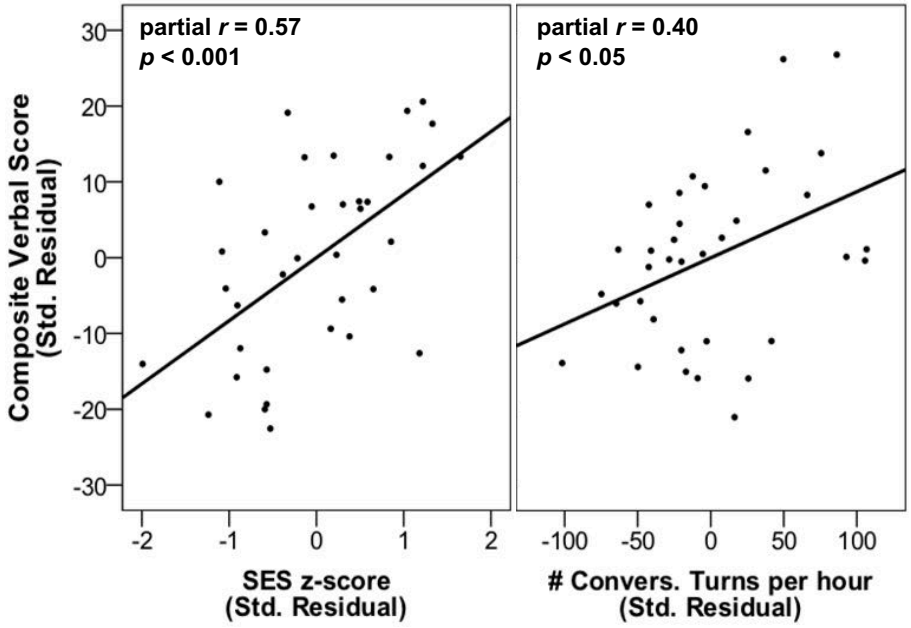


children ages 4-6

Romeo et al., under review

Number of Conversational Turns explain Verbal Scores **independent of SES**

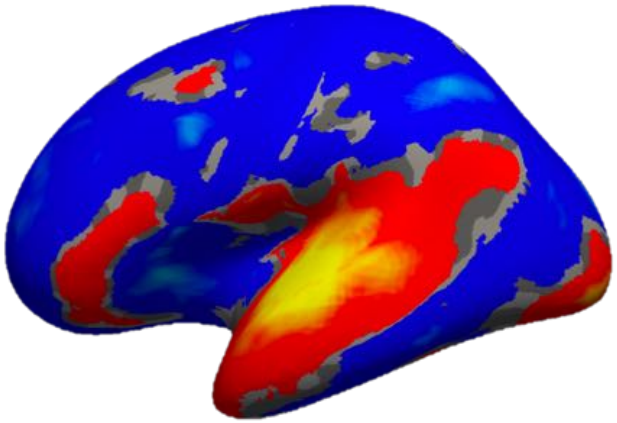




58 children ages 4-6 years

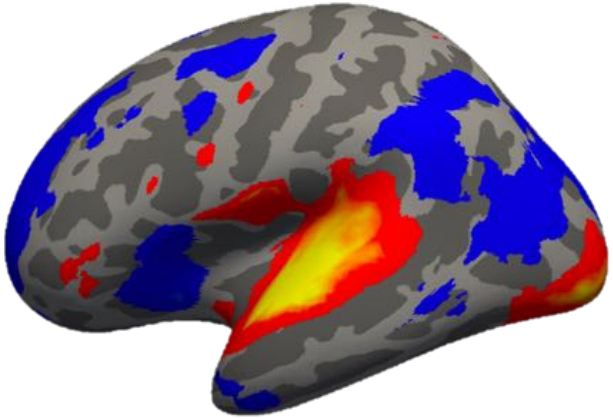
Romeo et al., under review

Combining LENA + fMRI task conditions



Forward Speech
task condition

-

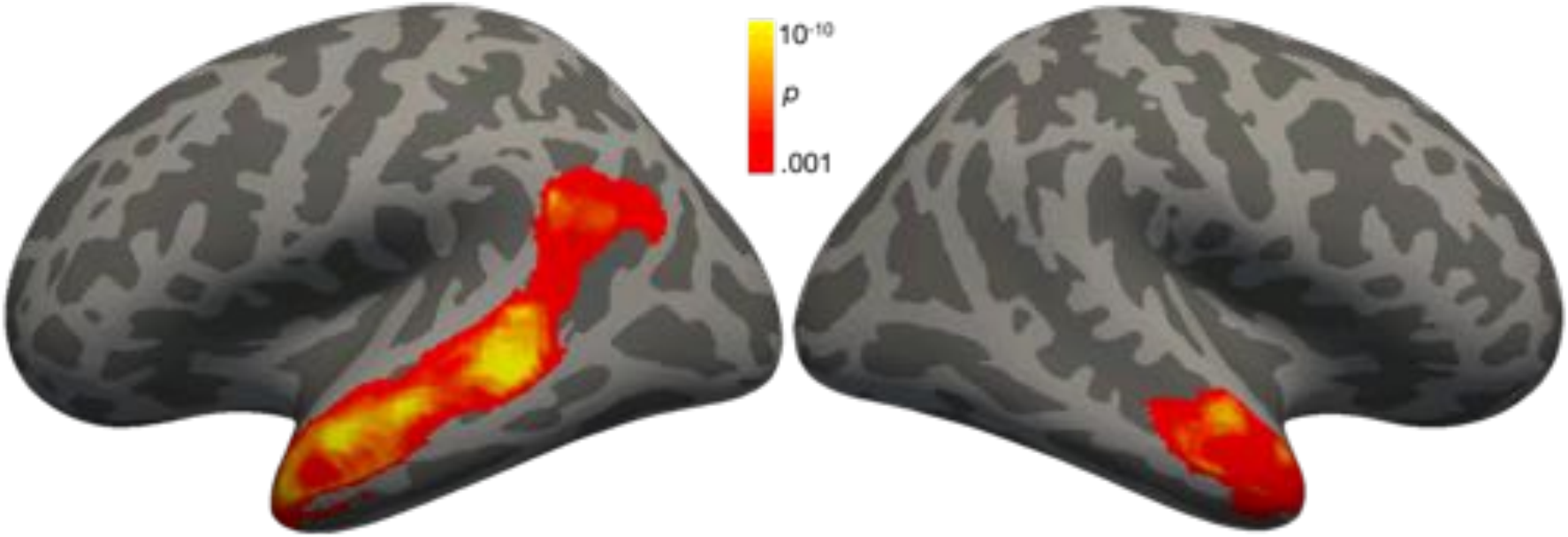


Backward Speech
task condition

=

Romeo et al., under review

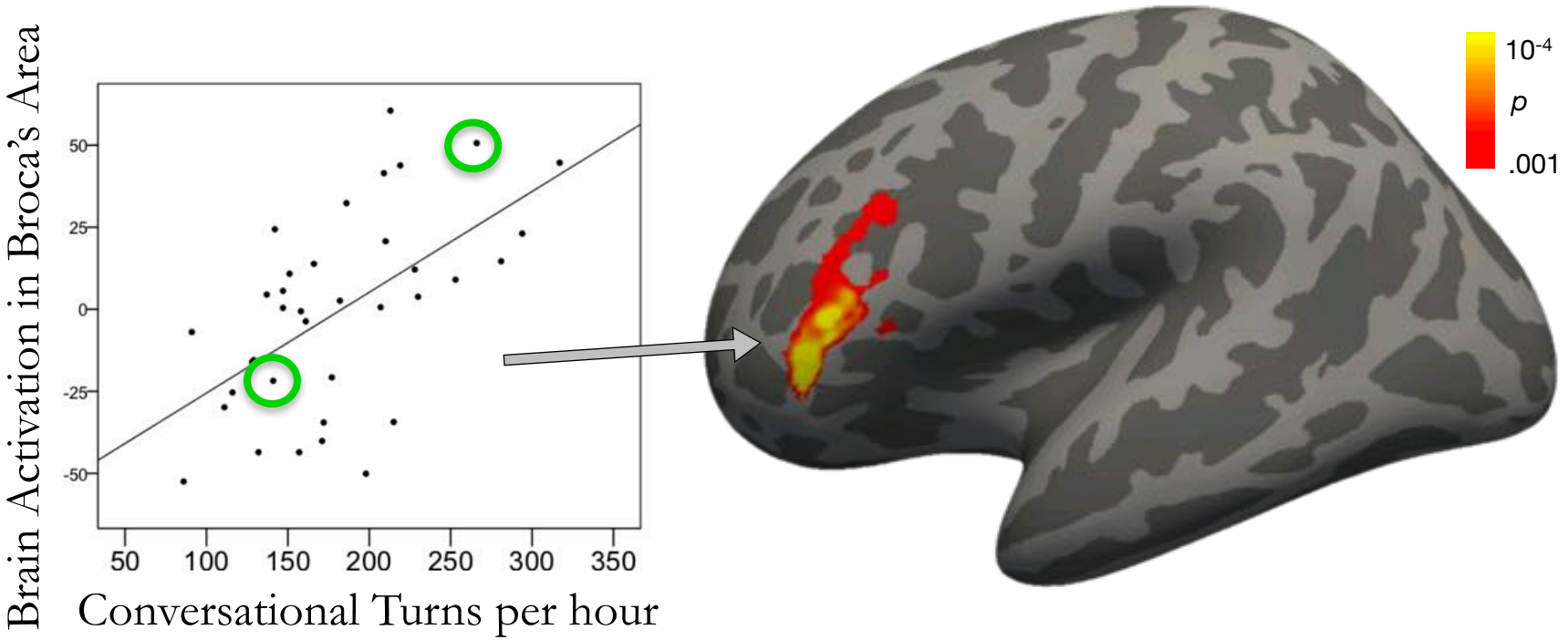
All participants use STS during language processing



Average of all participants during higher-level language processing

Romeo et al., under review

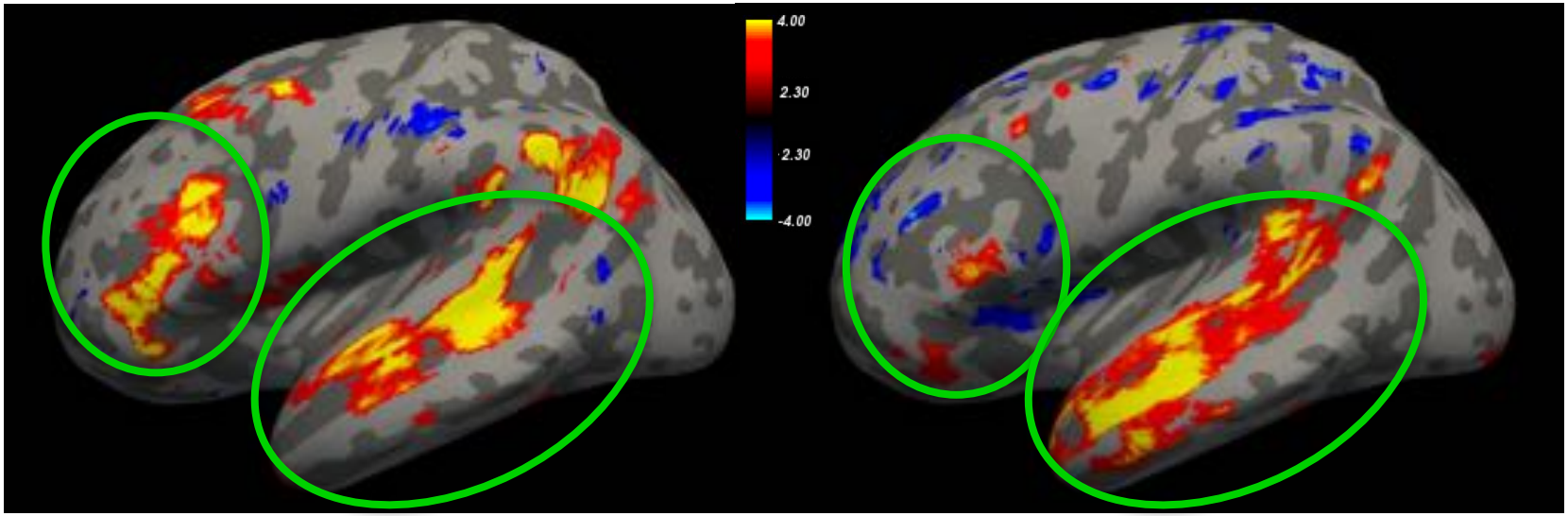
Greater Broca's activation in children who had more Conversational Turns



Romeo et al., under review

A tale of two brains

Two girls: similar age (5 years) & SES (high school + $50K total family income)

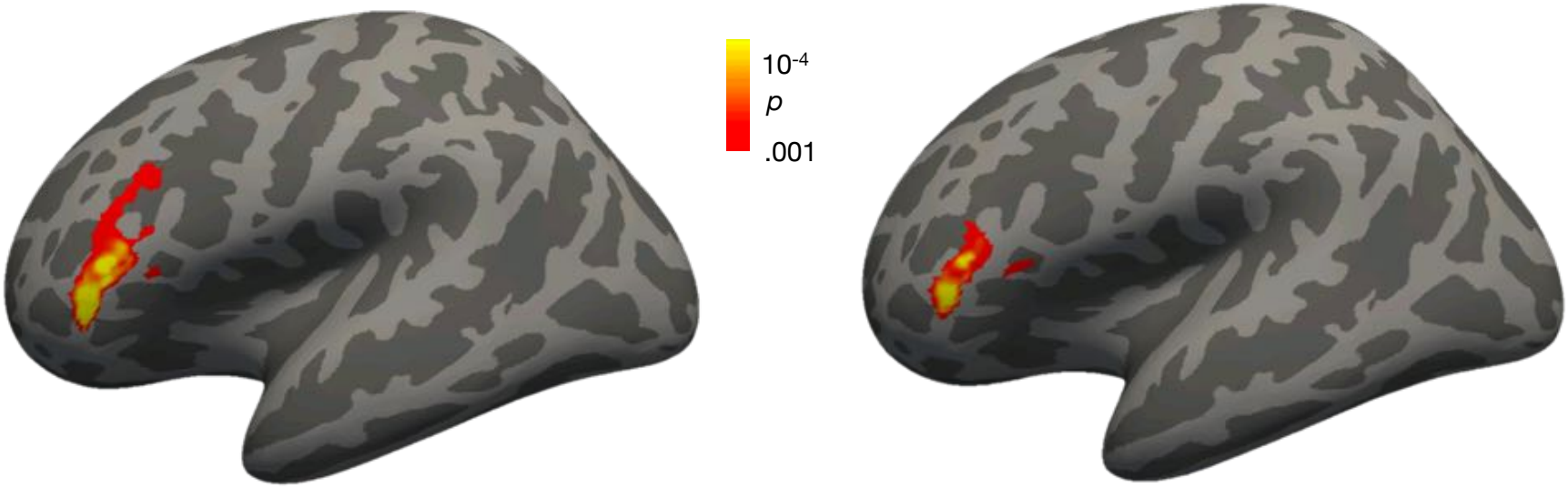


1,100 turns per day
Verbal score = 121

480 turns per day
Verbal score = 90

Romeo et al., under review

Greater Broca's activation in children who had more Conversational Turns **independent of SES**



Zero order correlation with # conversational turns

Correlation with # conversational turns, controlled for SES

Romeo et al., under review

Also independent of IQ, executive functioning, and adult or child speech alone

Correlation with # conversational turns, controlled for:

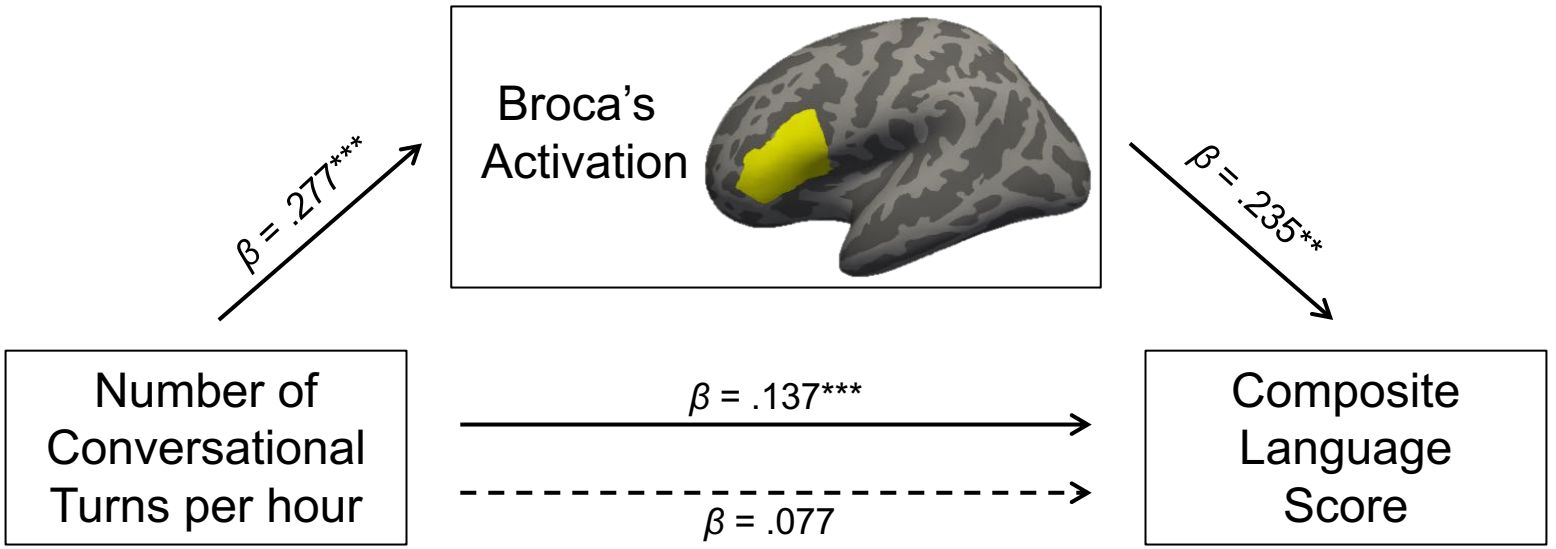
Verbal and nonverbal scores

Executive functioning

Adult words & child utterances

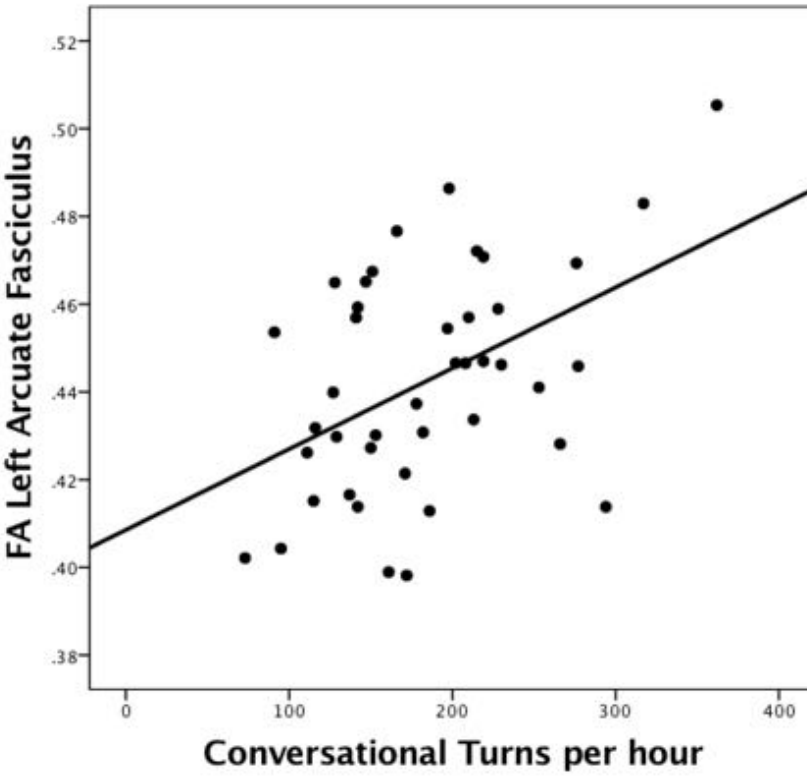
Romeo et al., under review

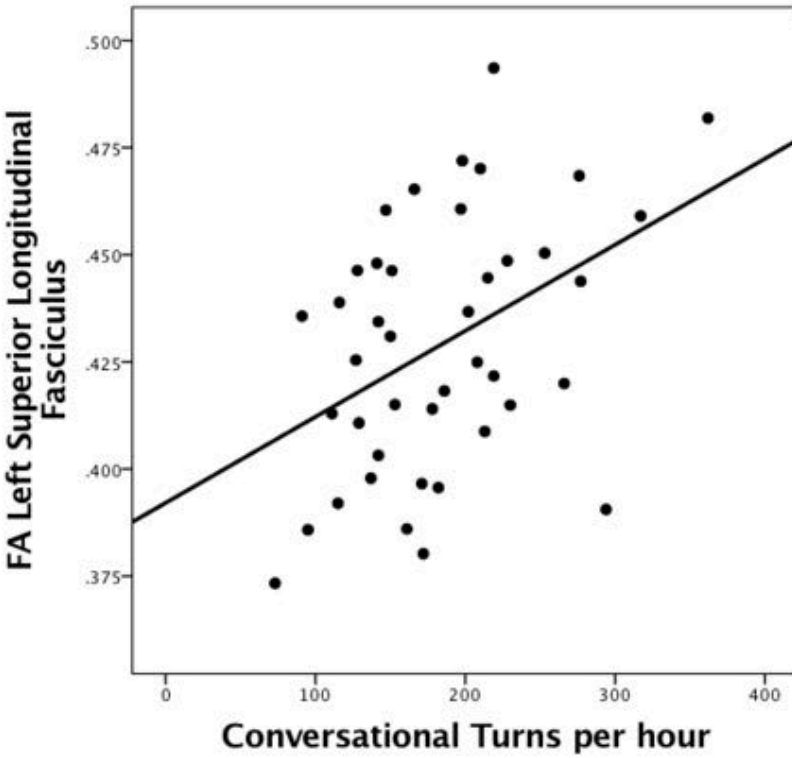
Broca's activation explains relation between conversational turns and language scores

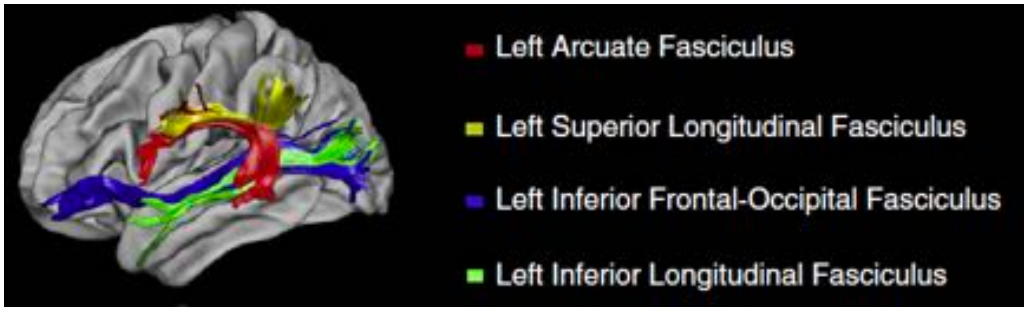


Romeo et al., under review

White matter and language exposure



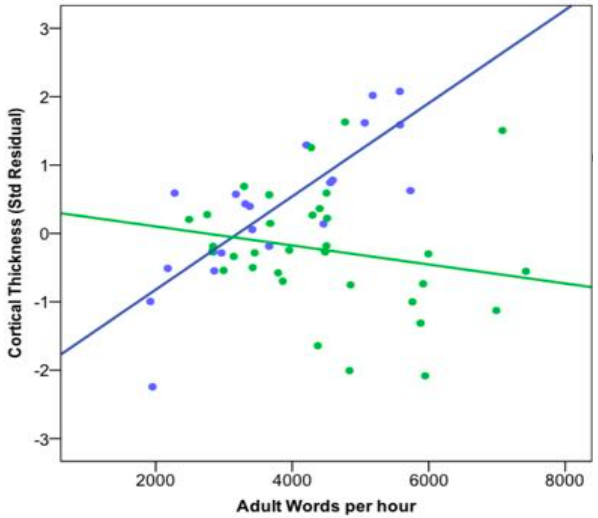


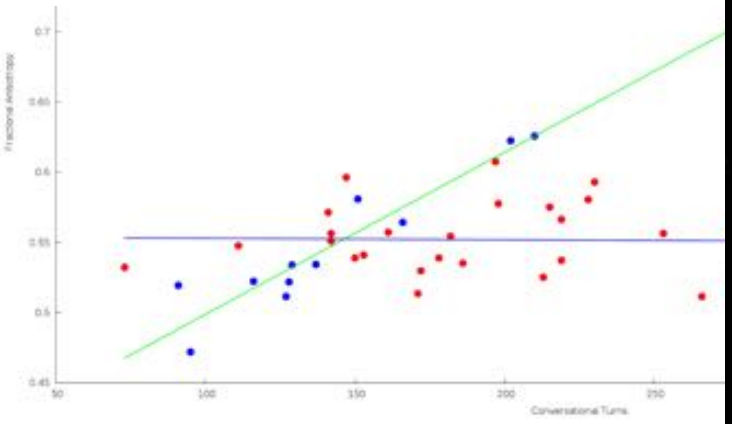


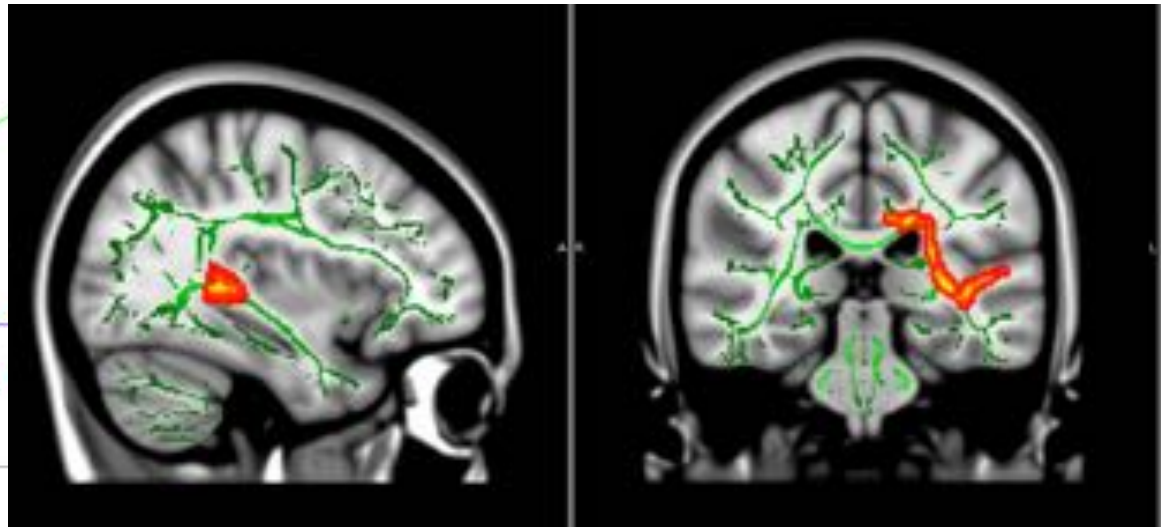
Romeo et al., in prep

Low-SES disproportionately sensitive to language exposure

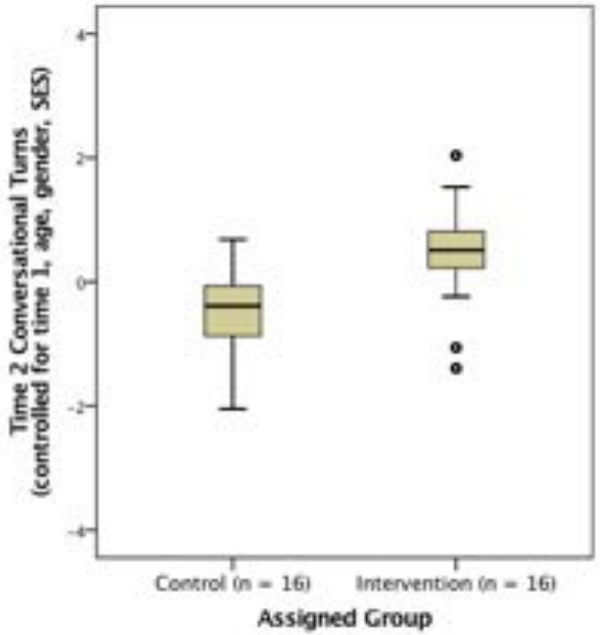
Structure of gray and white matter near "Wernicke's Area"

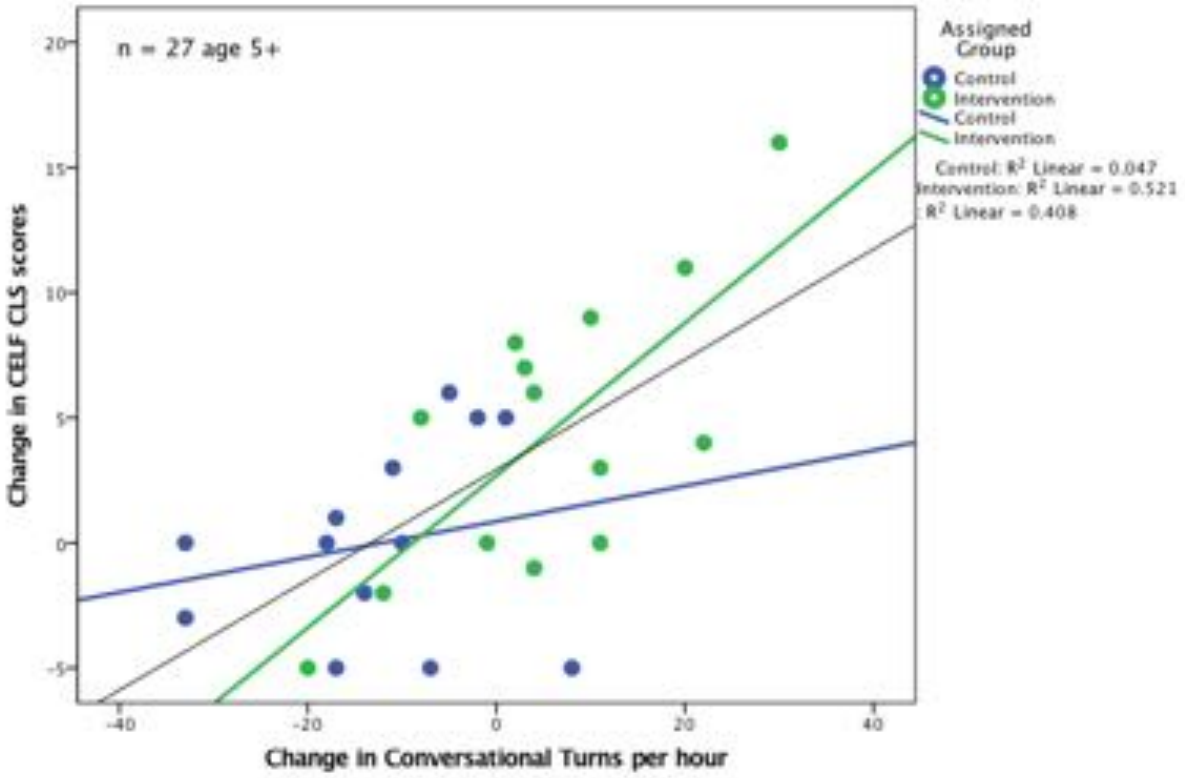






Is parent language malleable?



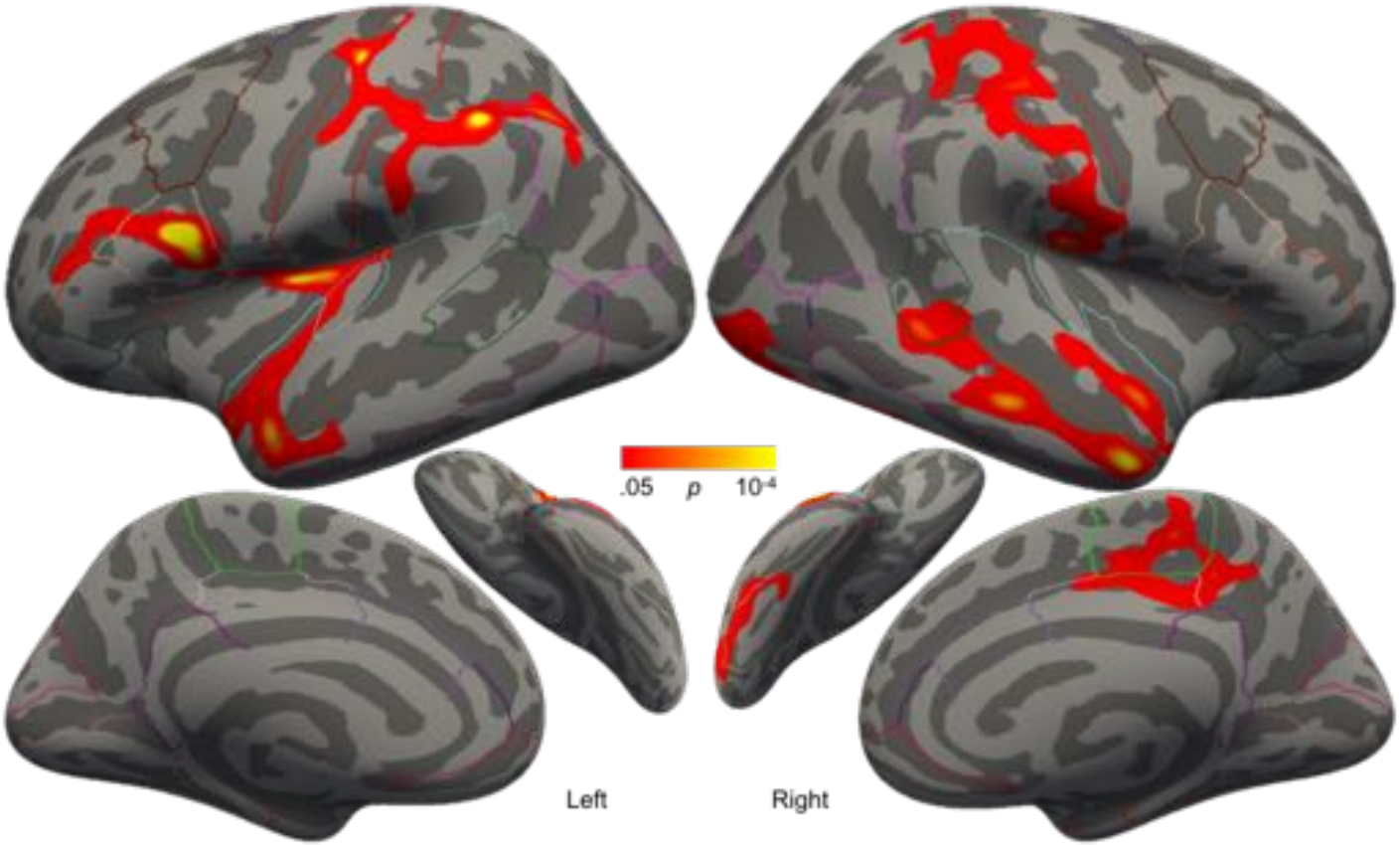


SES and Reading Disability (RD)

- Low-income students have a disproportionately higher rate of RD diagnosis Shifrer et al., 2011; Peterson & Pennington, 2015
- Studies of SES & cognition are typically conducted on "typically developing" children with scores in the near average range.
- Studies of RD are typically conducted on mid-to-high-SES convenience samples.
- Very limited neural research on SES + RD.

SES and Reading Disability (RD)

Children with RD show strong correlations between SES and cortical thickness in key language areas, over and above reading scores.

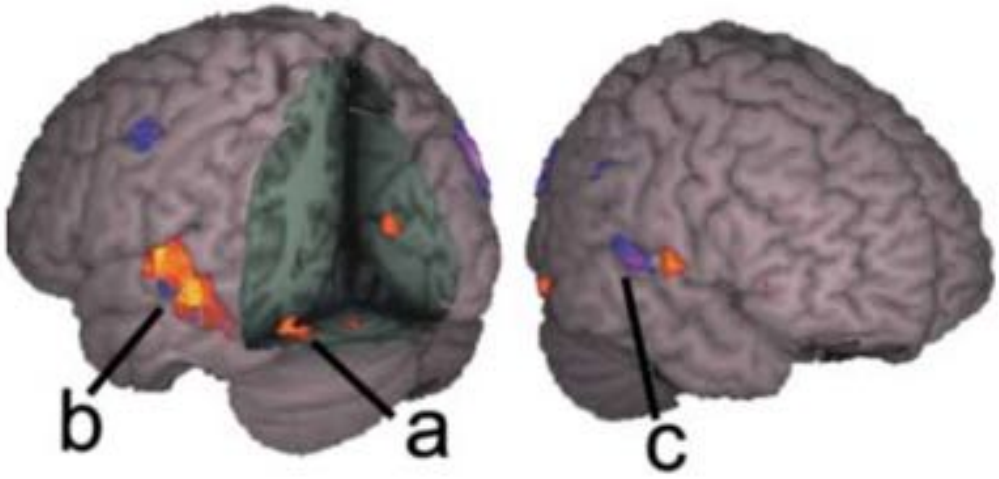


Romeo et al., *Cerebral Cortex*, 2017

SES modulates reading-related brain activity

Lower SES children exhibit stronger brain-behavior correlations between phonological awareness scores and brain activity during decoding. Noble et al., 2006

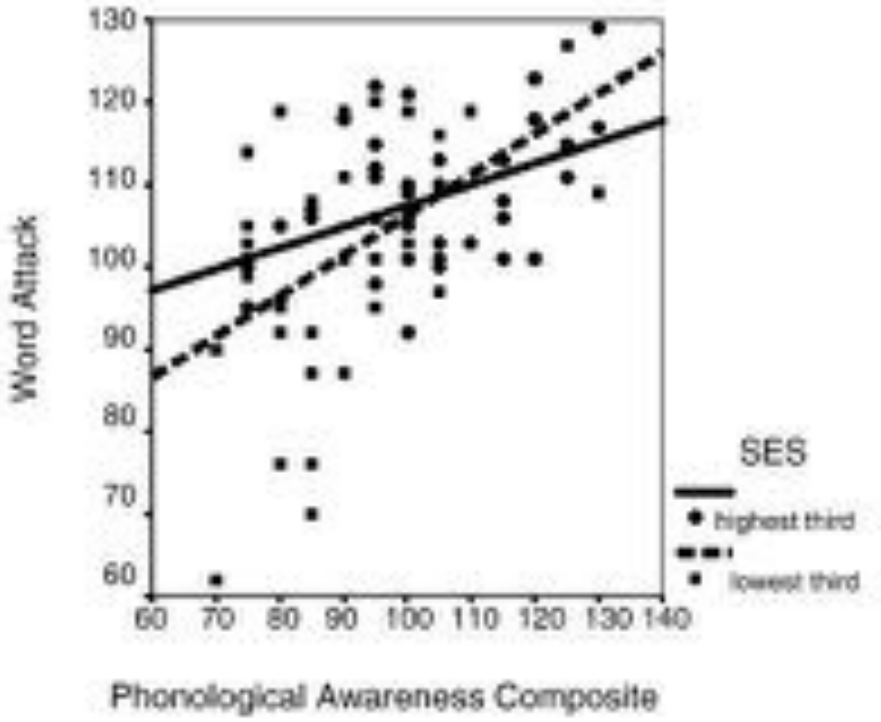
- Red/yellow = lower SES
- Blue/purple = higher SES



"Perhaps exposure to reading-related activities has led to increased recruitment of the left fusiform gyrus during reading, despite poor phonological skill."

No "safety net" for low SES readers

- Childhood SES can interact with other genetic or neurological risk factors.
- Low SES multiplies the negative effect of low phonological awareness on decoding skills. Noble et al., 2006



"Advantaged parents might have the resources to increase environmental exposures or seek out alternate educational strategies [for a child with low PA].
In contrast, less advantaged parents may be less likely to recognize low phonological skill or be able to provide the resources necessary to overcome such a difficulty."

Summer Time Adventures in Reading and Learning (START) study

Summer reading intervention

- 40 SES-diverse children
- Intensive small group instruction
  4 hours x 5 days x 6 weeks = over 100 hours
- Lindamood-Bell "Seeing Stars" multisensory approach to train orthographic and phonological processing

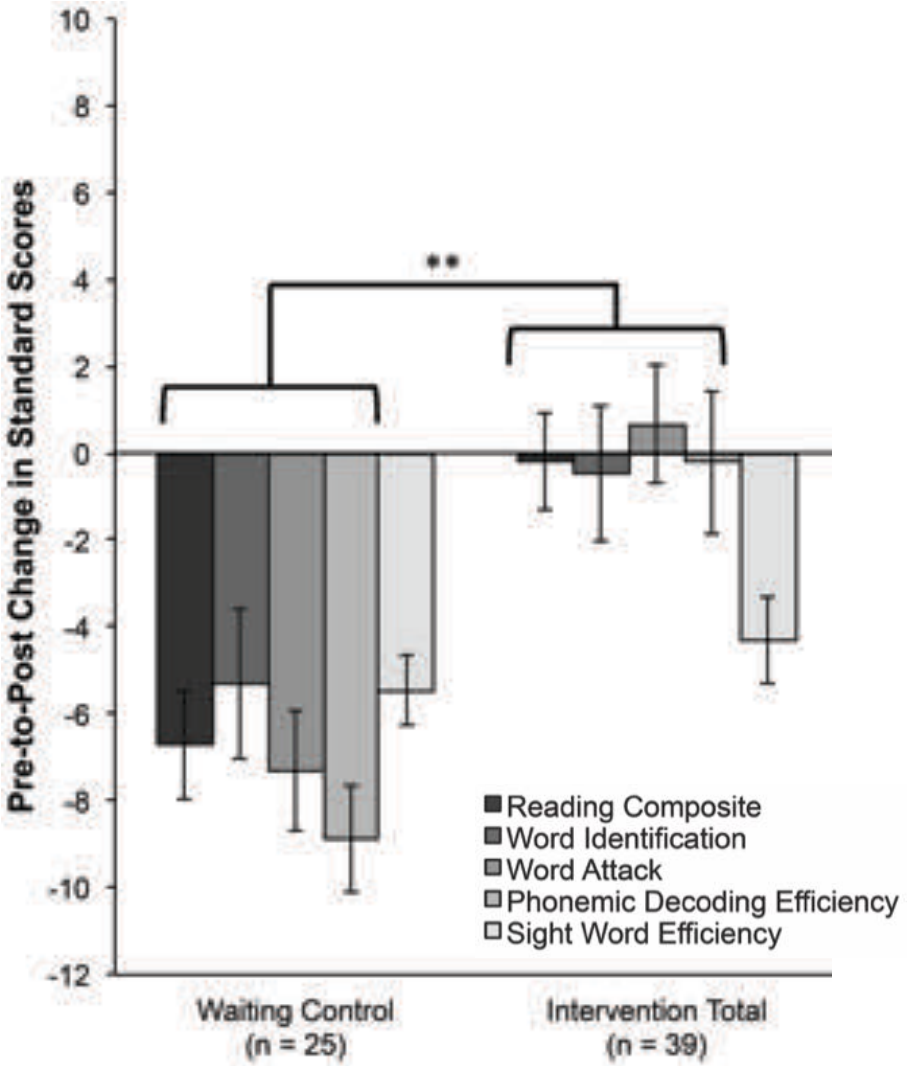
Waiting controls

- 25 children had "summer as usual"

Reading assessments & MRI before and after

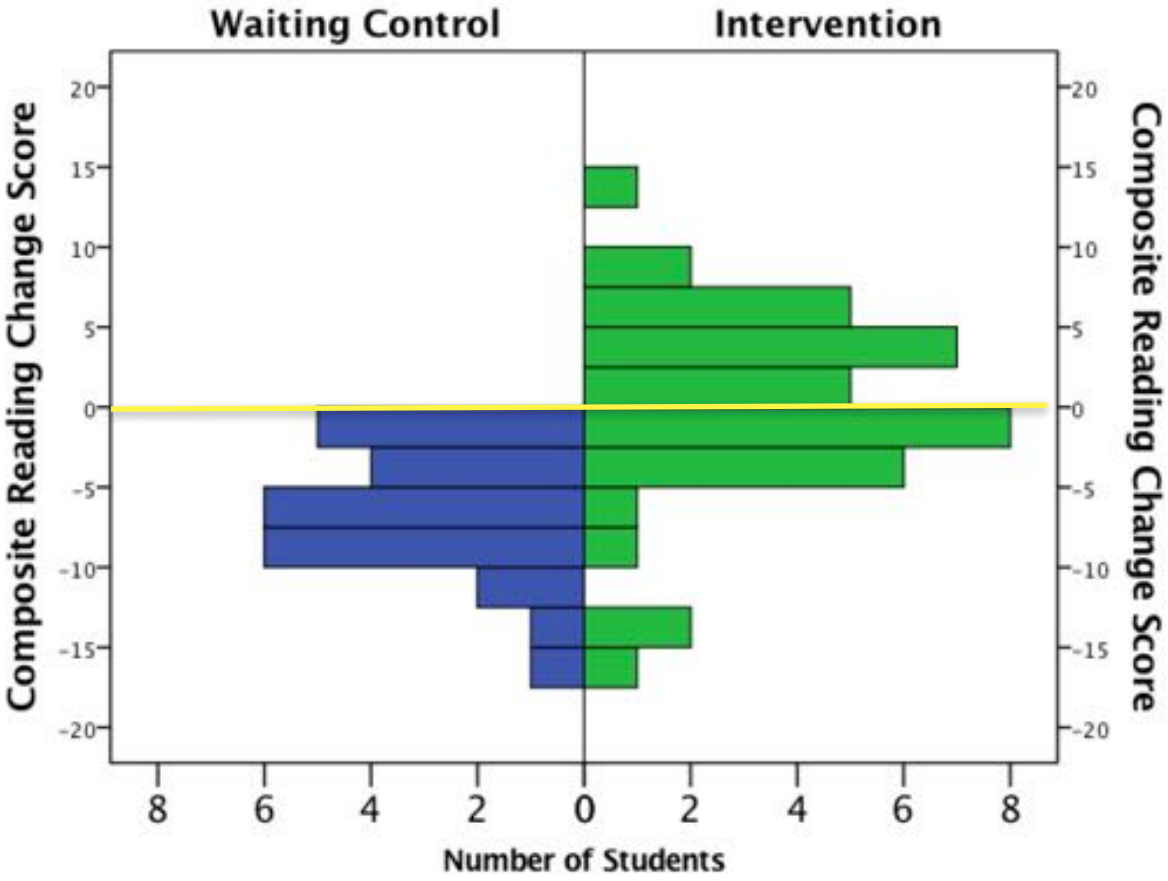
Christodoulou et al., 2015; Romeo et al., 2017

Summer slide avoided



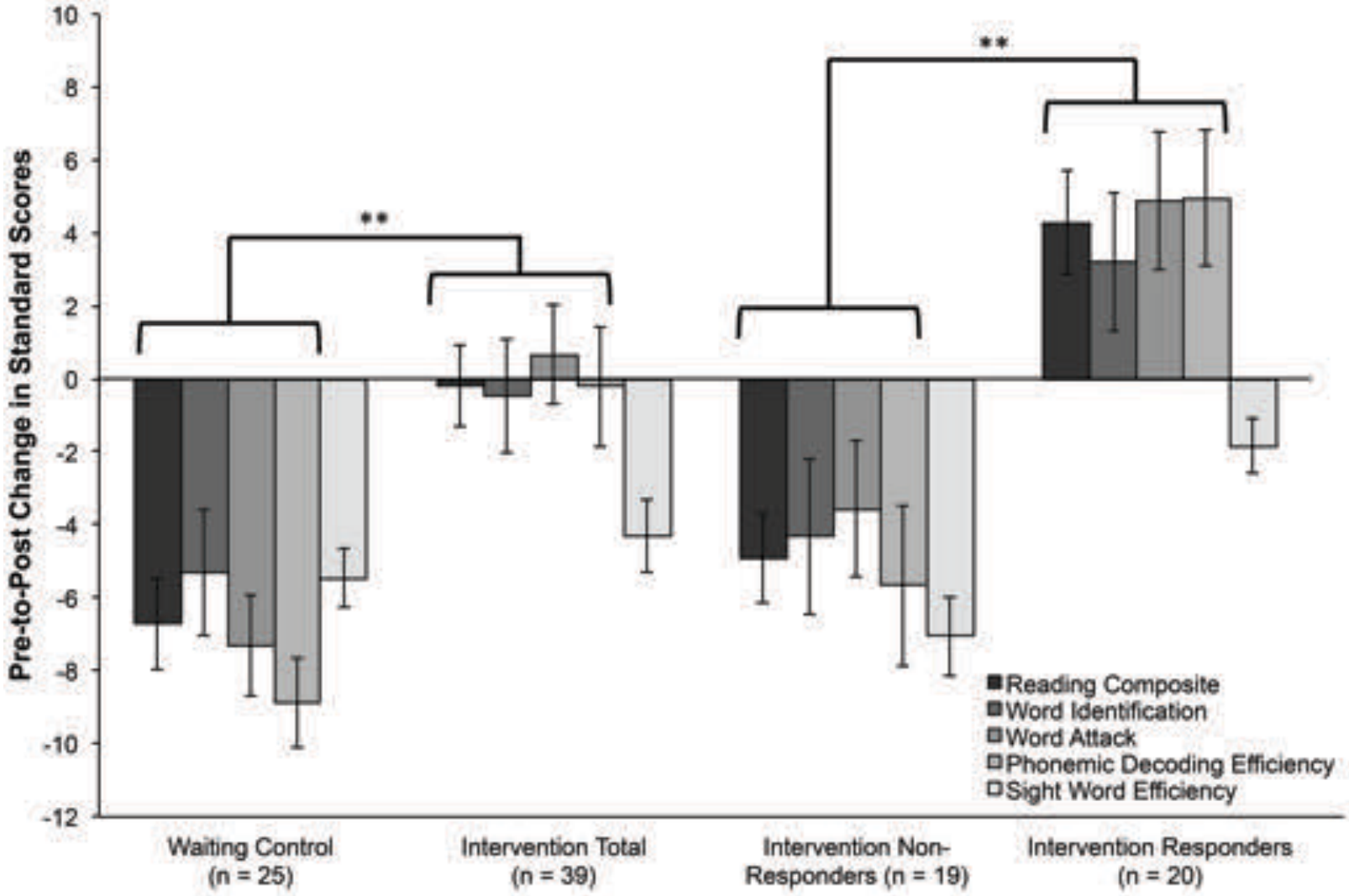
Romeo et al., *Cerebral Cortex*, 2017;
Christodoulou et al., *J. Learn. Disabil.*, 2015

Variation in treatment response



Romeo et al., *Cerebral Cortex*, 2017

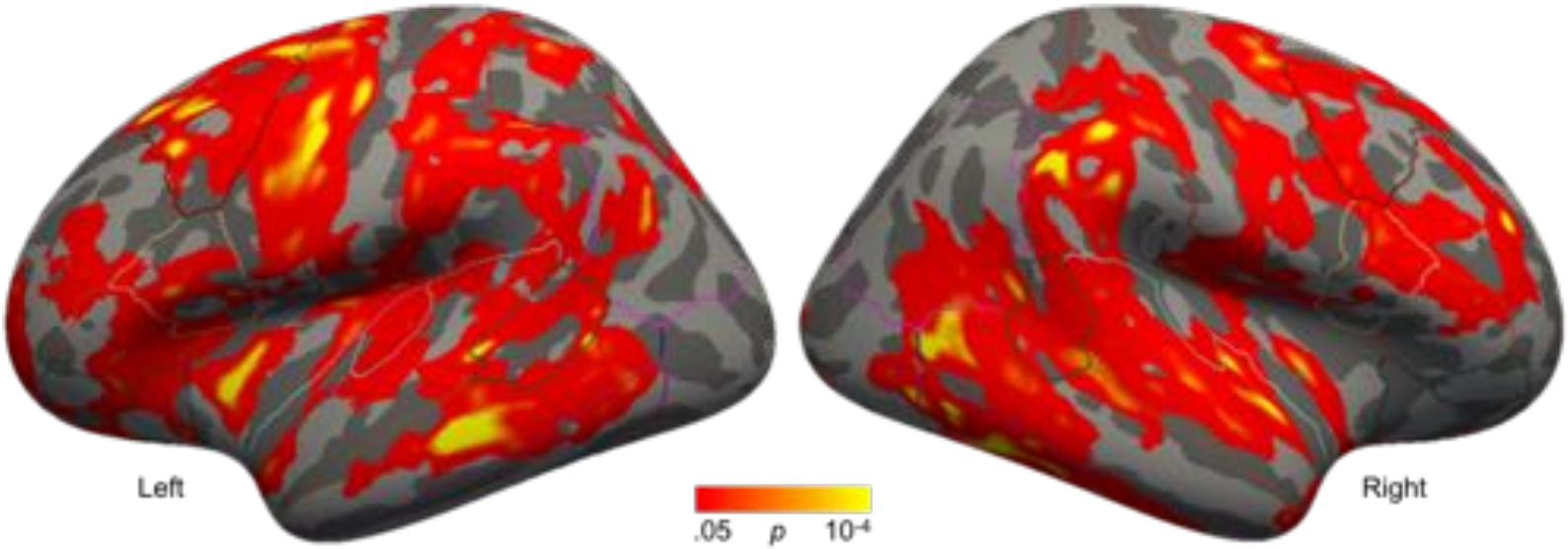
"Responders" and "Non-Responders"



Romeo et al., *Cerebral Cortex*, 2017

Neuroplasticity after Intervention

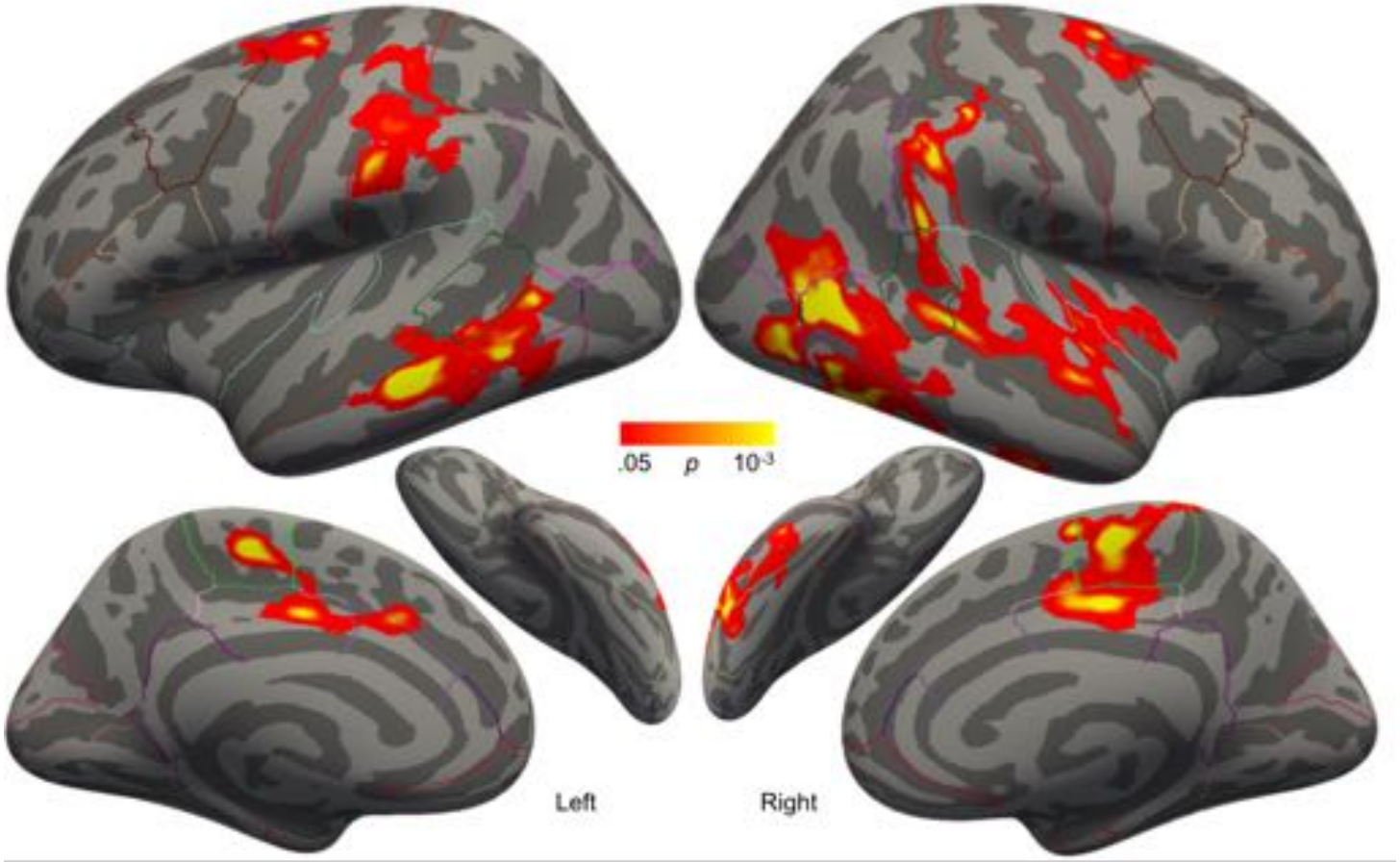
Treatment Responders show vast cortical growth



Treatment NonResponders & Waiting Controls show no significant cortical changes

Romeo et al., *Cerebral Cortex*, 2017

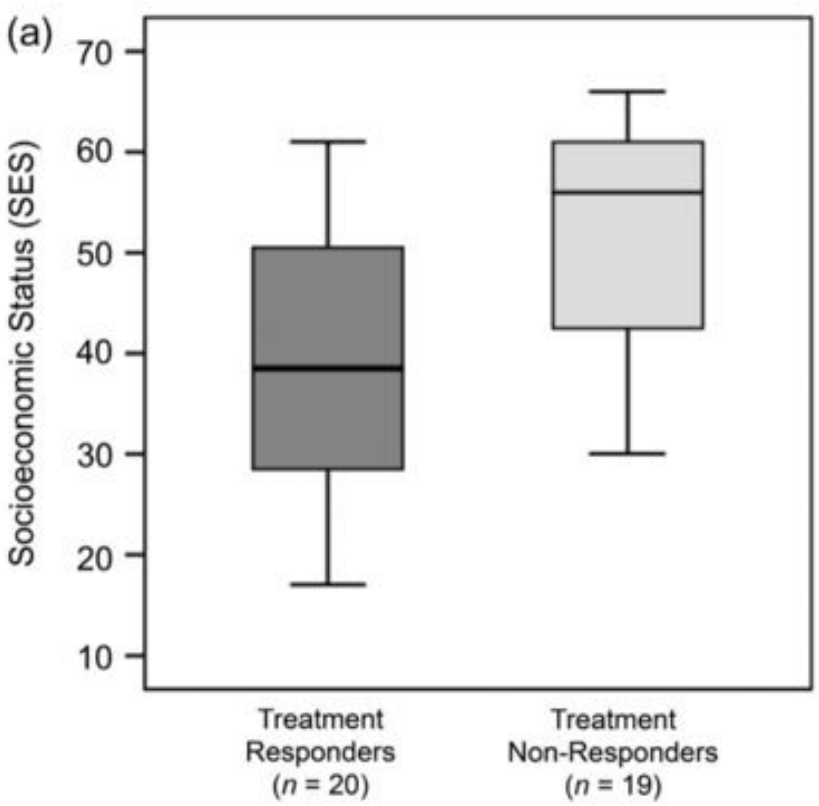
Responders > Non Responders

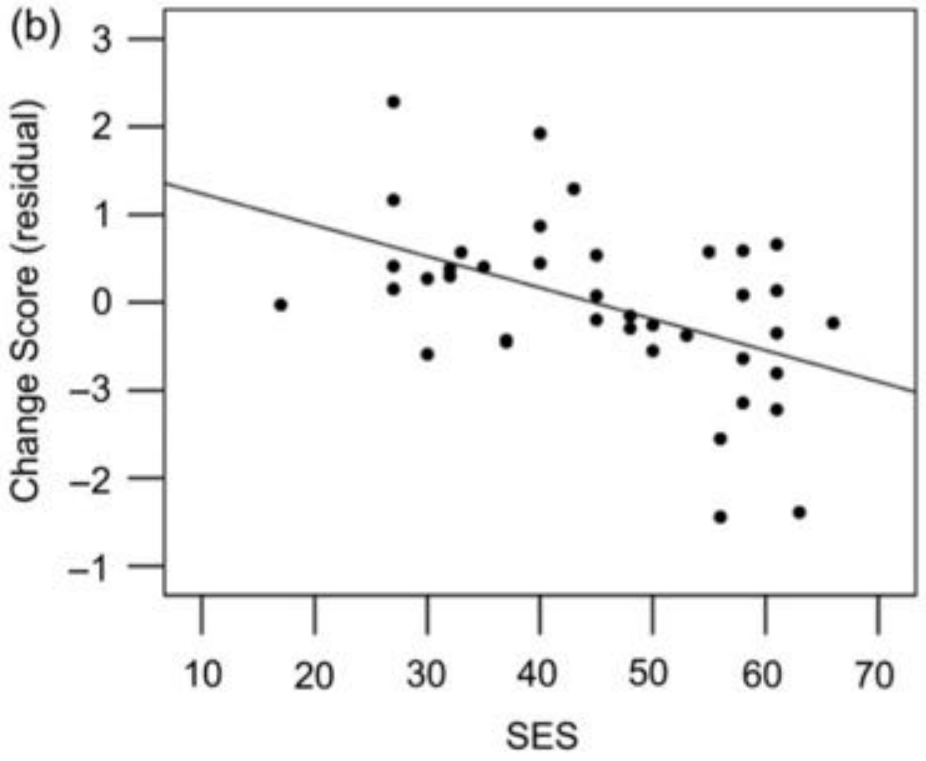


Significant differences between groups
(longitudinal symmetrized percent change)

Romeo et al., *Cerebral Cortex*, 2017

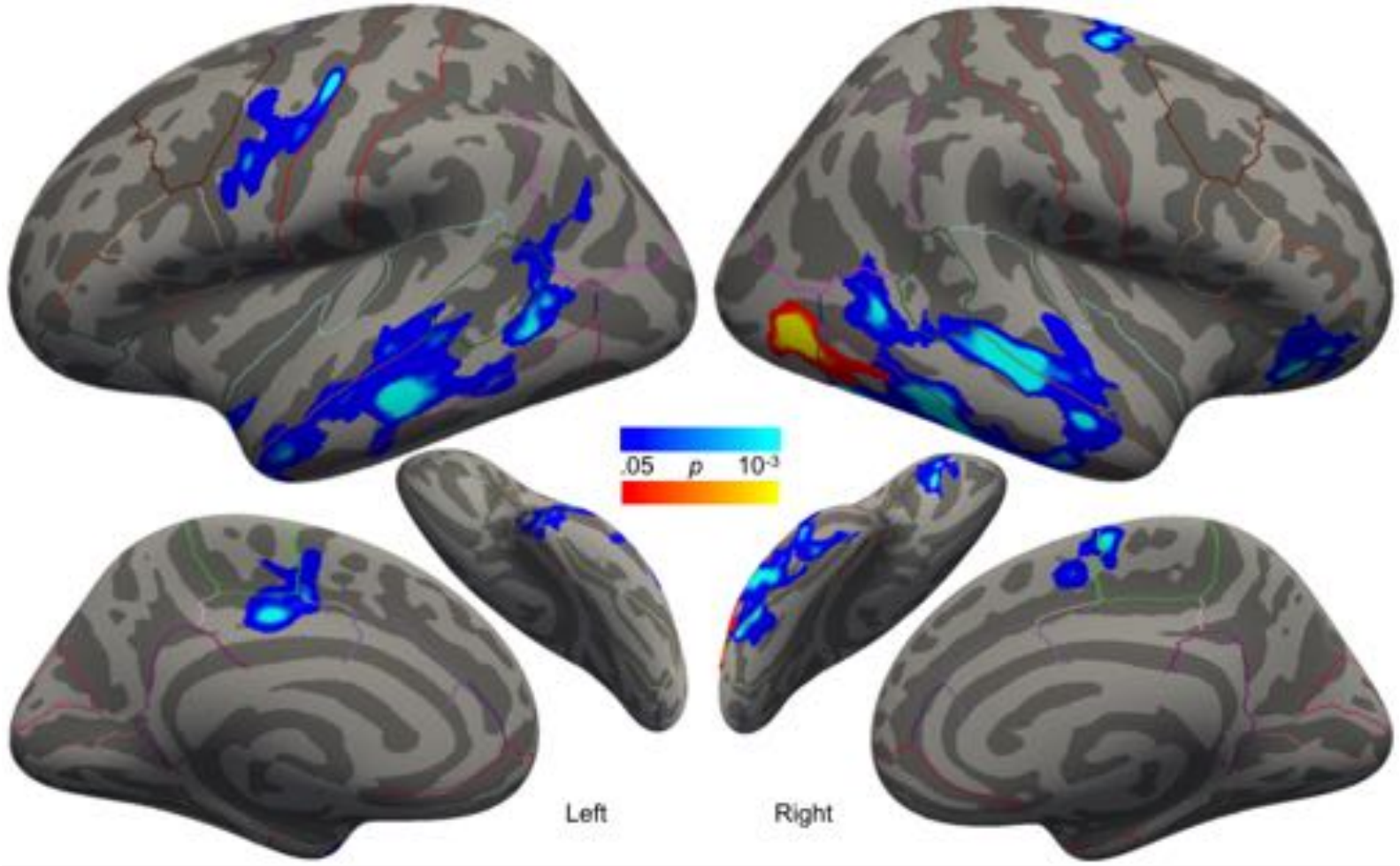
SES alone predicts treatment response





Romeo et al., 2017

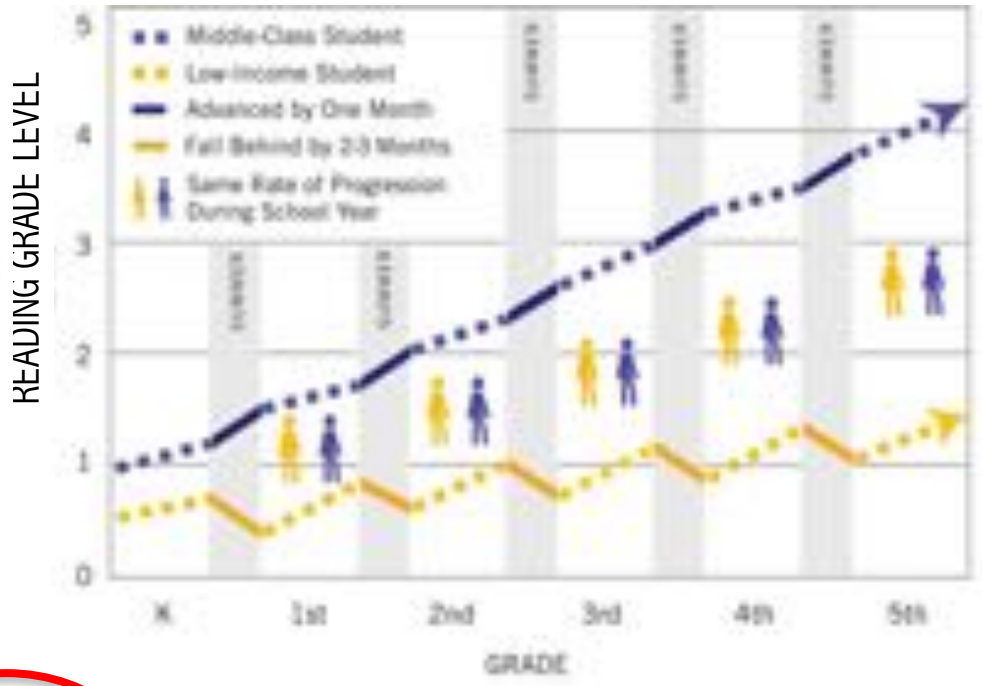
Lower SES ☞ Greater Cortical Growth

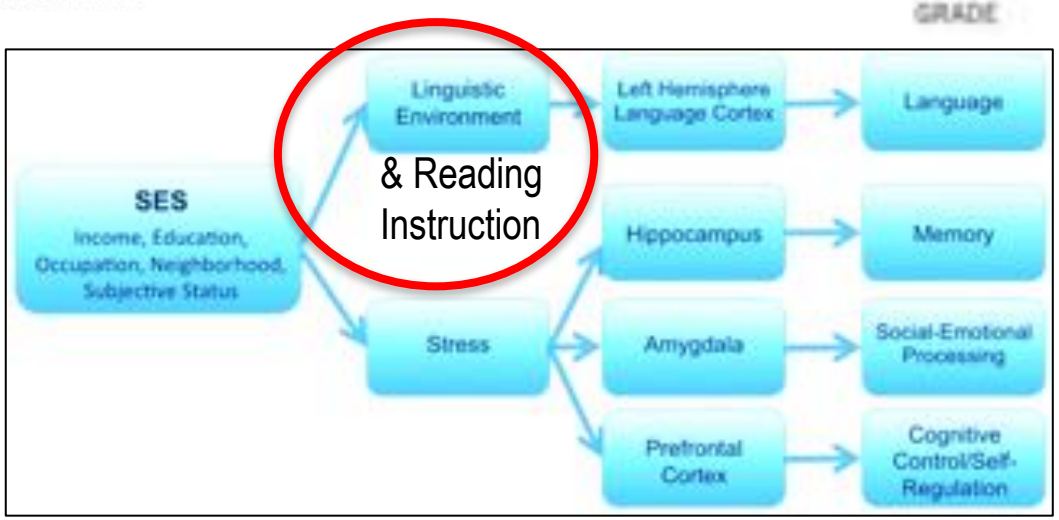


Romeo et al., 2017

SES, Homes, Reading & Language

"30 Million Word Gap"





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