Language in children with early brain injuries: behavioral and imaging evidence of plasticity

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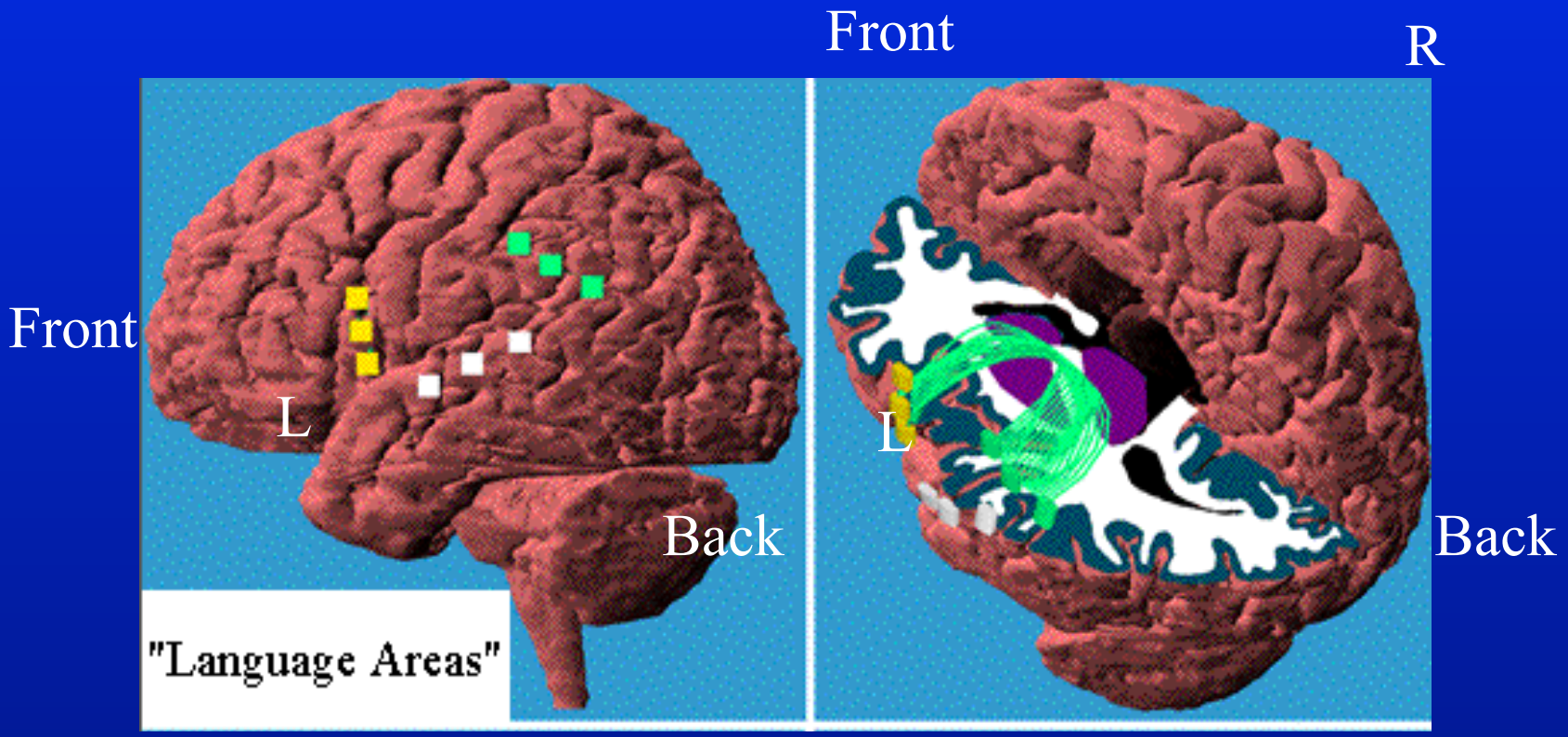
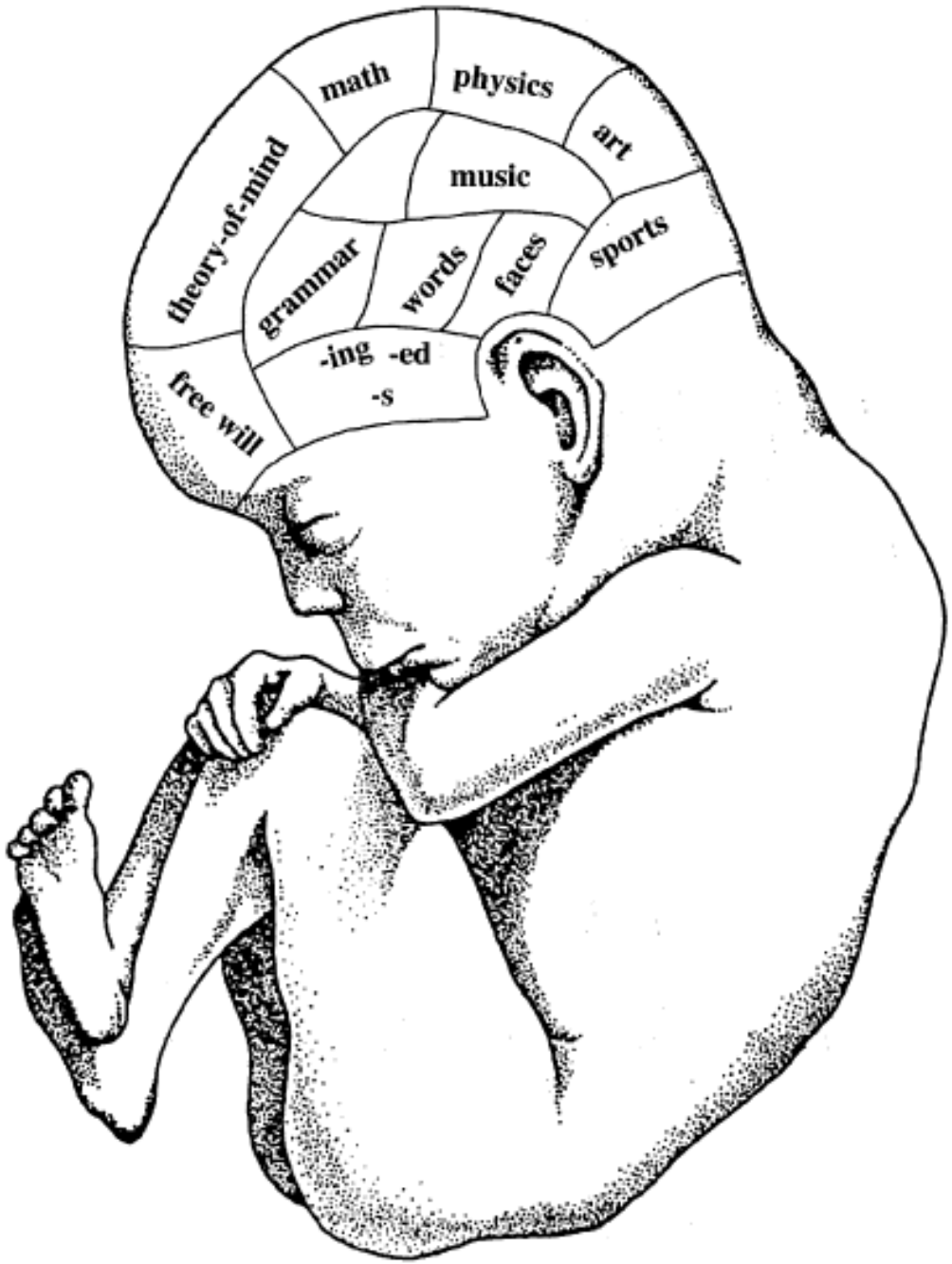
Outline

- Preformation/Emergentism -- Seven theories
- Development of language in preschool children with early unilateral brain injuries
- Performance at school age
  - Formal measures
  - Sentence comprehension strategies
  - Information processing tasks
- fMRI to uncover patterns of reorganization of language

Classic theory: Language modules in adult brain

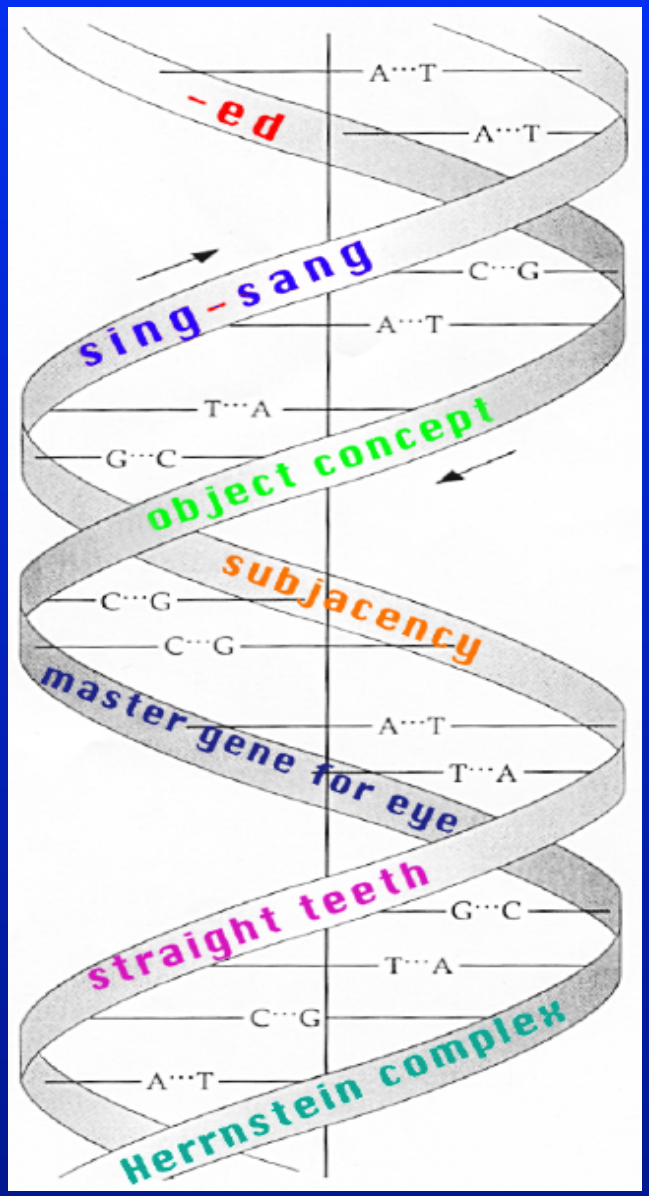


Modules from birth?



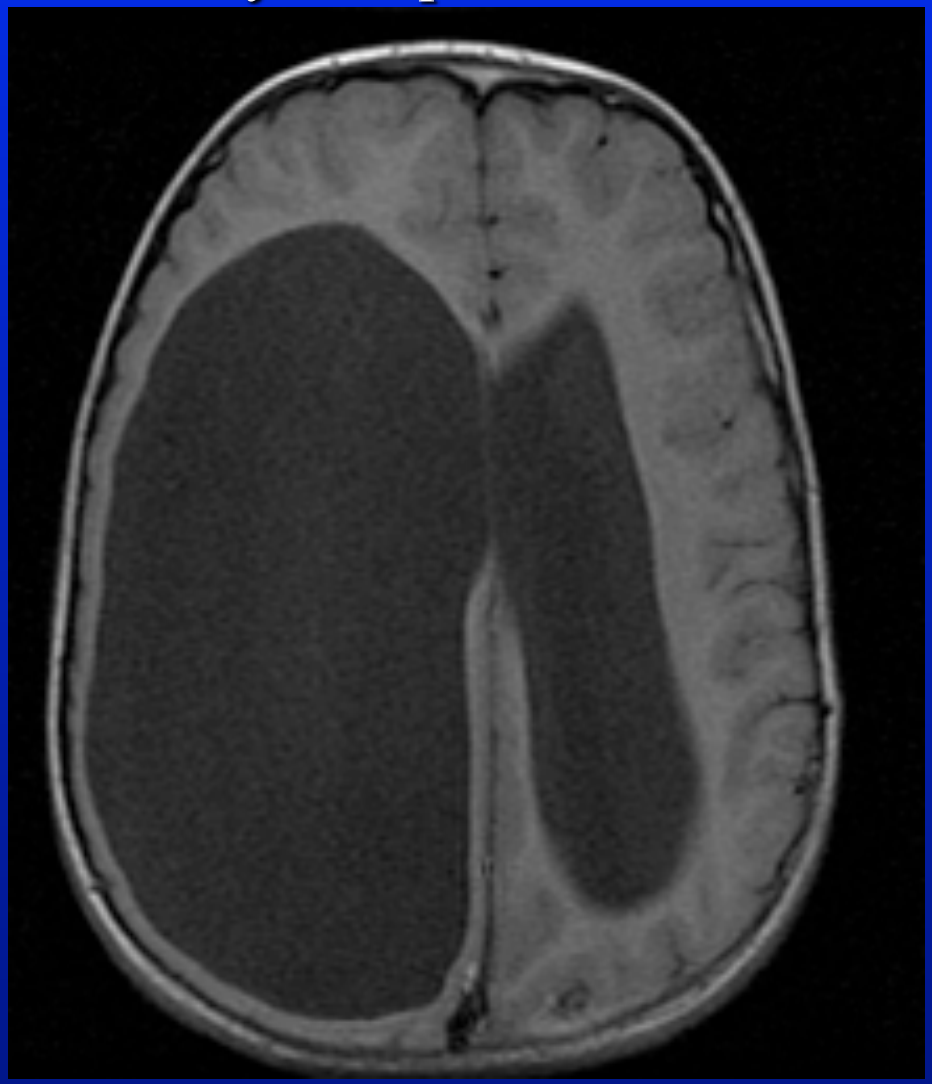
A toolkit

A Gene for the Past Tense?



Achilles' Heel of Modularity:

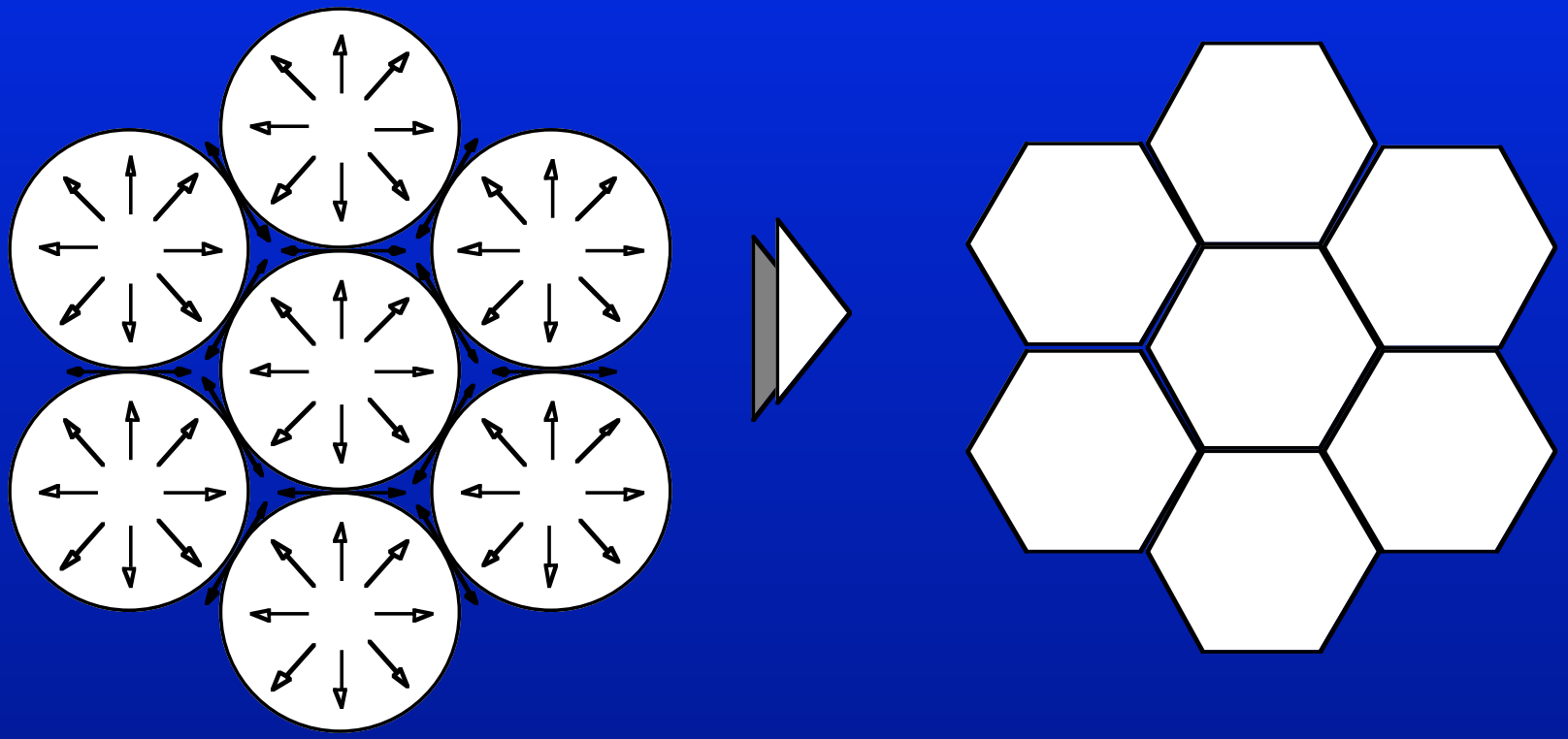
a child with marked hydrocephalus and normal language



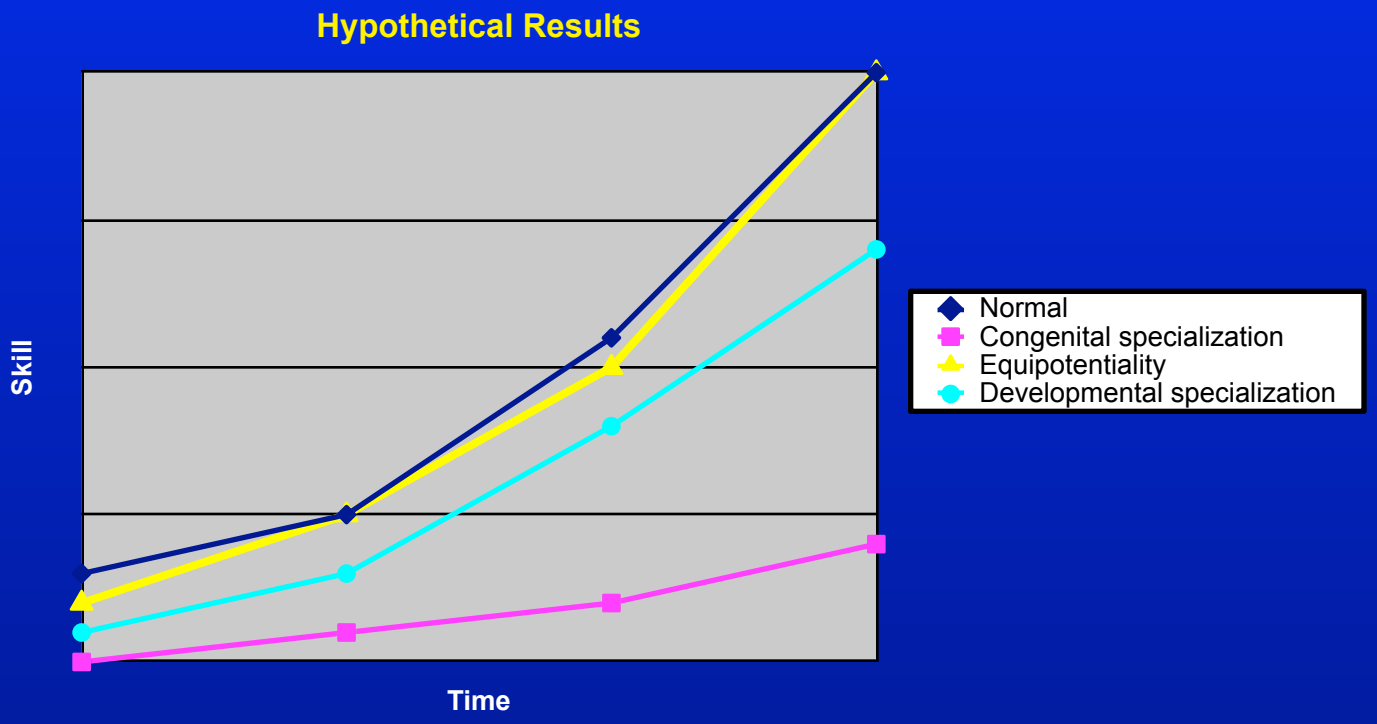
Alternative theory: Emergentism

- Language areas not highly circumscribed nor highly specialized, though LH dominant
  - RH becomes activated for various components or levels of difficulty
  - After injury, recovery may be possible with training

Structure in Honeycombs

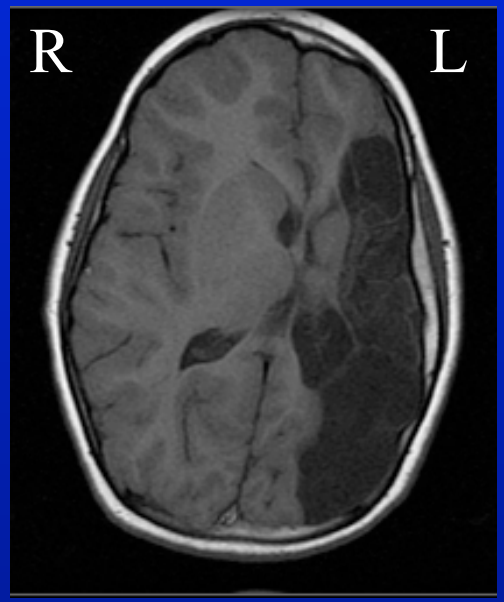


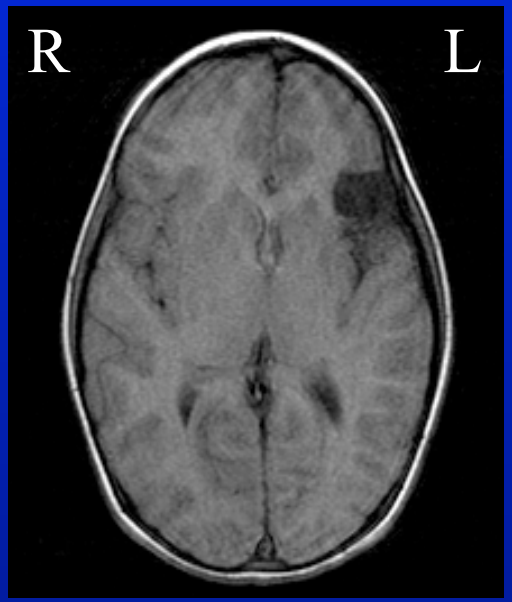
What happens if early damage?

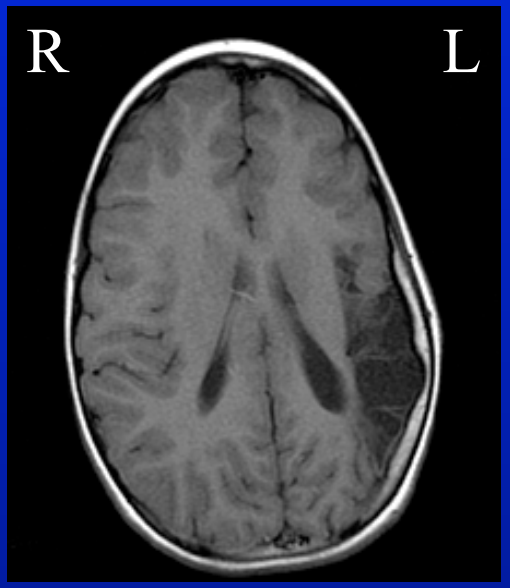


Children with early brain injury

Front

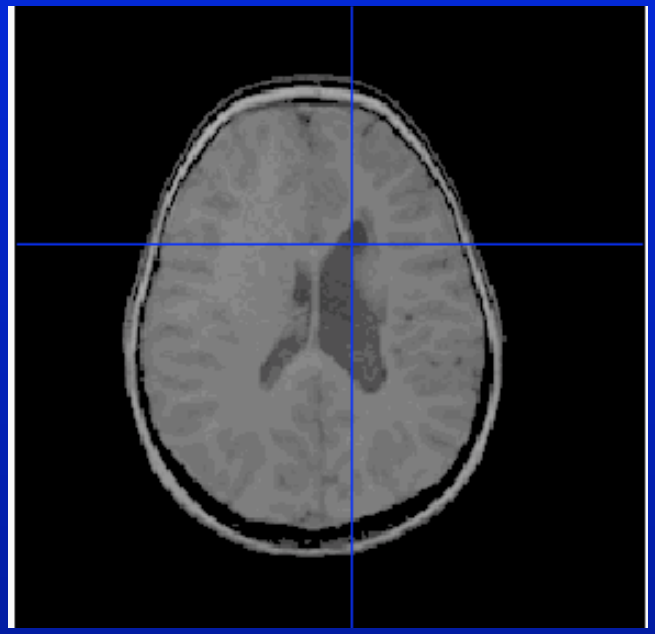






Back

MRI scans of PVH



Child with early brain injury

Seven observed patterns

1. Preferential language sparing
2. Cognitive crowding
3. Hemispheric equipotentiality

4. Contralateral recruitment

5. Local recruitment

6. White matter commitment

7. Late rigidity

Lack of direct evidence

- No direct evidence of crowding
- No direct evidence of use of contralateral homologs
- Unclear evidence on equipotentiality
- No direct evidence of local recruitment
- No direct evidence on actual organization

Open Developmental Questions

- Initial delay -> catchup -> final parity?
  OR
- Sparing -> cognitive crowding -> decline in late acquisitions (math, reading)

- Exactly how does brain reorganize?

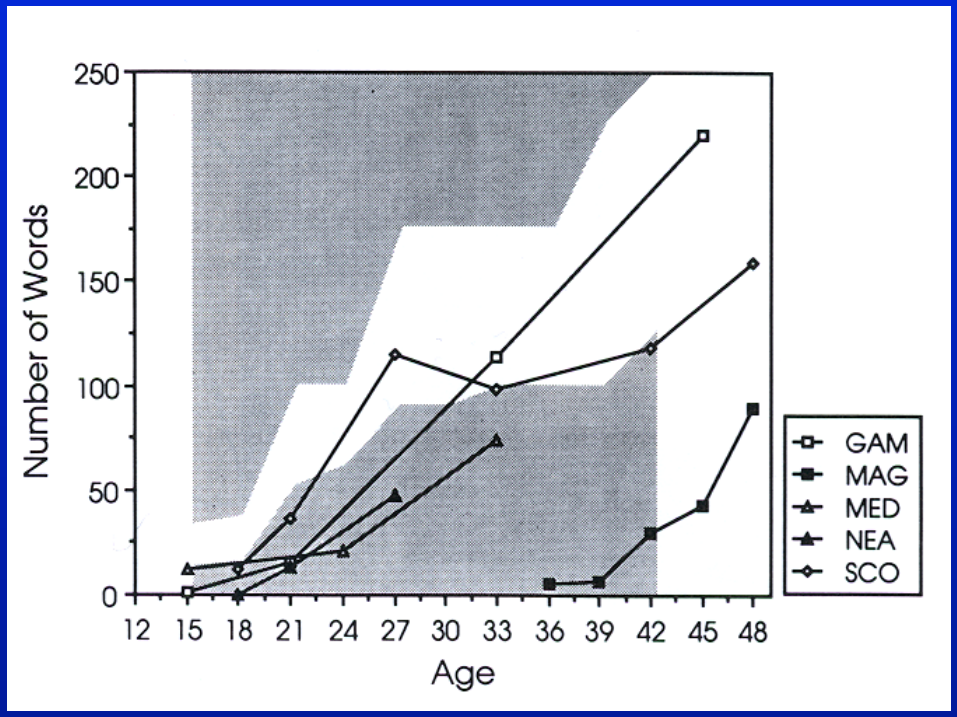
Language development in children with early brain injuries

(Feldman, Holland, Kemp, Janosky, 1992)

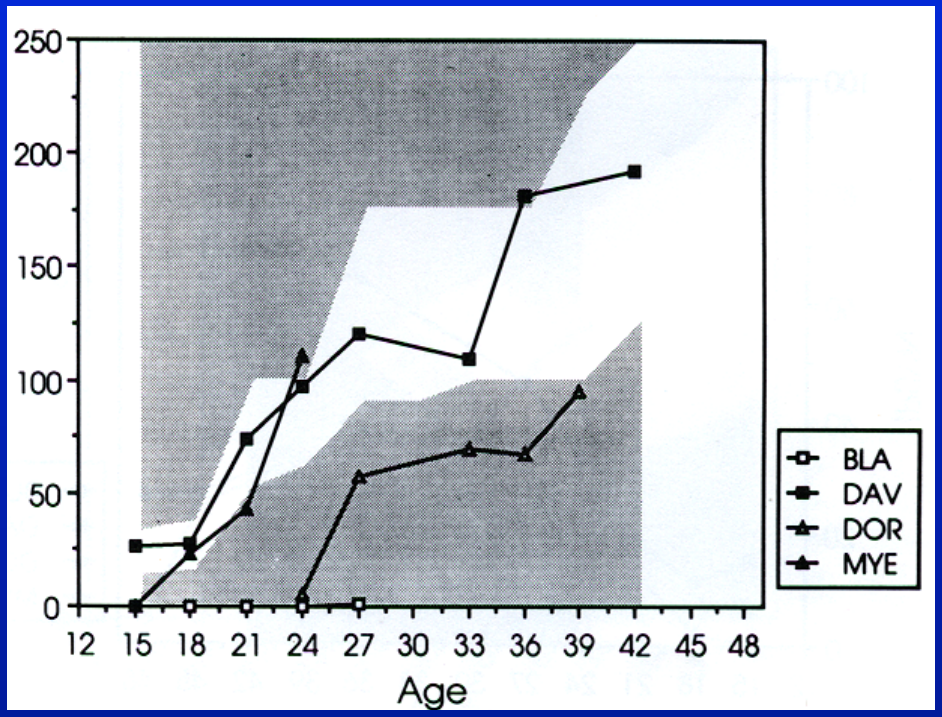
- To describe the changes over time in language skills of young children learning language
- Multiple observations of parent-child communication
  - Lexicon—Number of words
  - Syntax—MLU and IPSYN
- Compare children with unilateral LH and RH damage to children developing typically

Vocabulary growth

LH injury

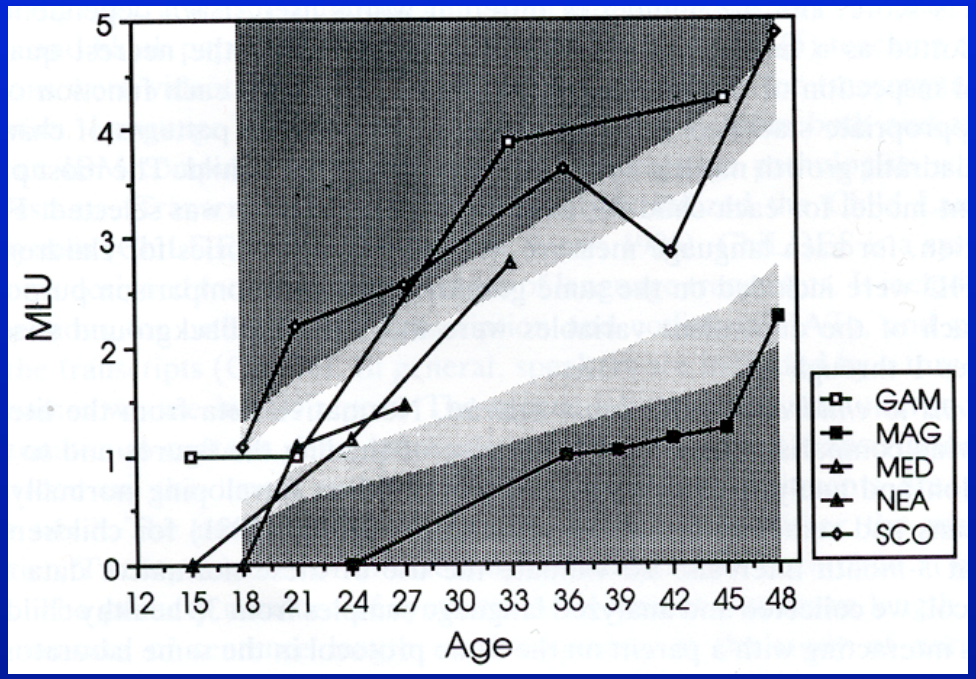


RH injury

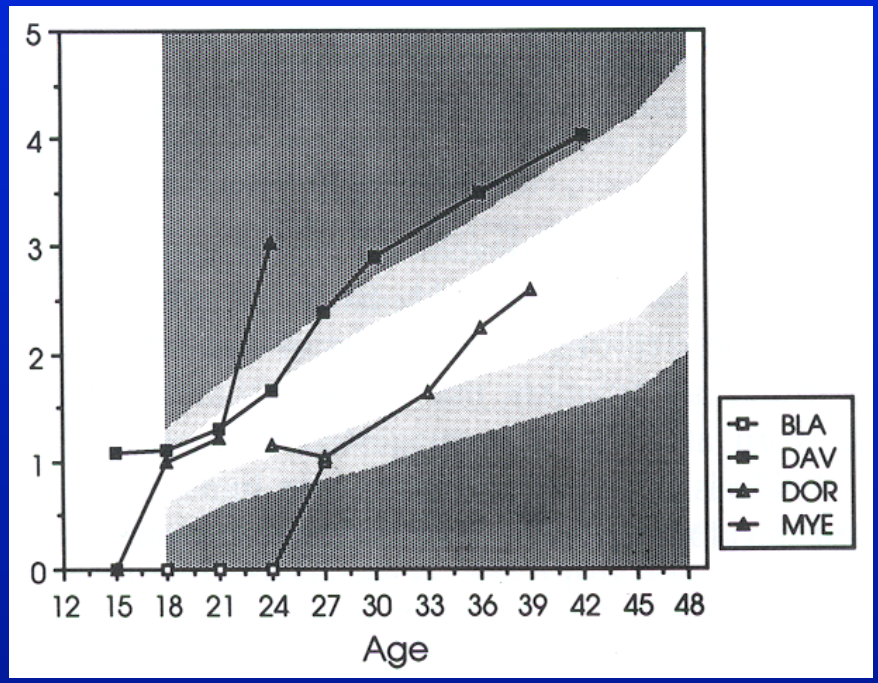


Average sentence length

LH injury

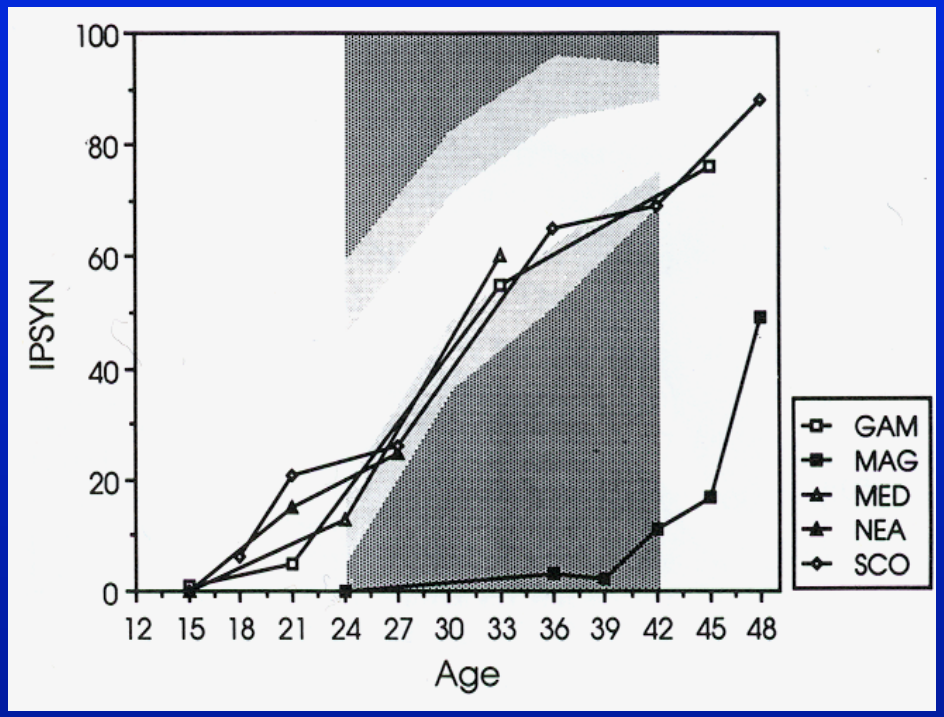


RH injury

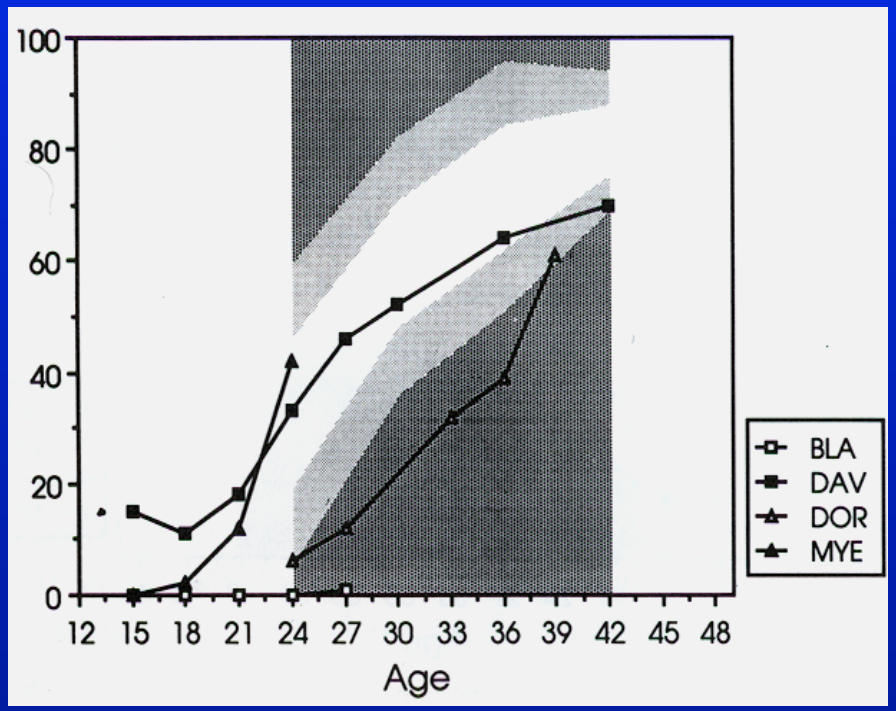


Grammatical complexity

LH injury



RH injury



Summary and Questions

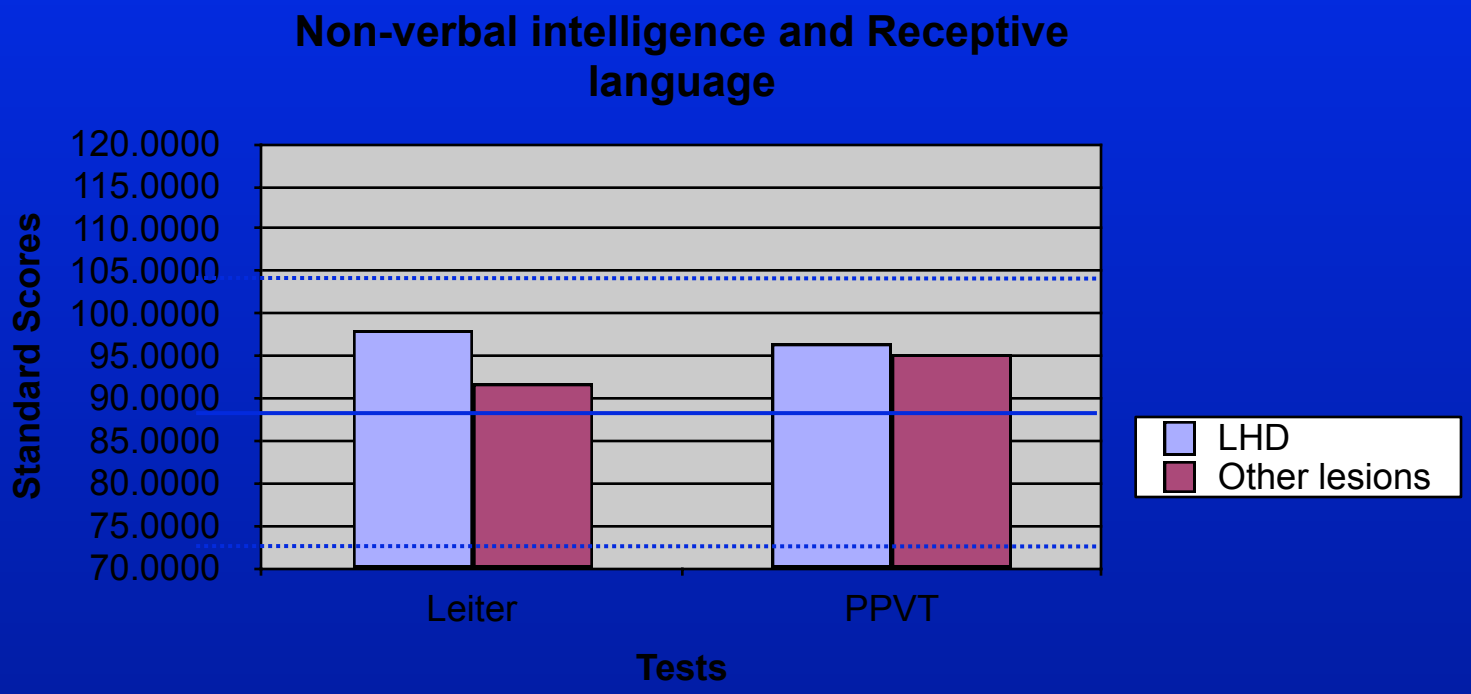
- Children with early brain injuries may show initial delays and then near normal rates of development
- Suggests takes longer to organize the damaged system
- Issues
  - What are the best measures to assess early language in these children? Types versus tokens, competence versus performance
  - Would larger sample reveal greater difference?
  - What happens as the children reach school age?

Formal testing at school age

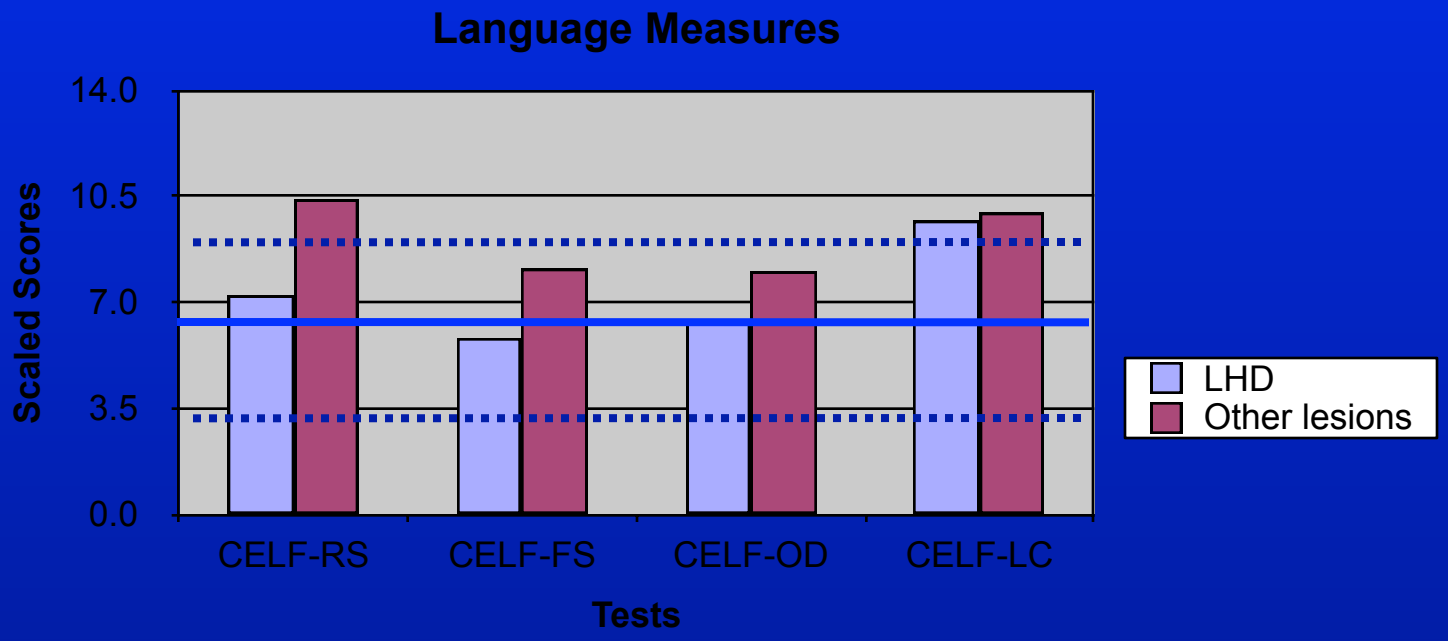
(MacWhinney, Feldman, Sacco, Valdez-Perez, 2000)

- Goal: to determine how children with early brain injuries perform on formal measures at ages 6 to 10 years
- Measures
  - Non-verbal intelligence test (Leiter International Performance Scales)
  - Receptive vocabulary (PPVT-R)
  - Language Functions (CELF-R)

Formal Testing Results



Formal Language Measures



Sentence comprehension study

(Feldman, MacWhinney, Sacco, in press)

- Goal: to determine the cues children use to determine the agent of the action in sentence-comprehension
  - Syntax is area of alleged weakness in many studies of children with acquired injuries
  - Functional tasks better than judgments
  - To isolate sentence comprehension strategies, need task with minimal other processing demands: simple input, no memory load, and non-verbal (pointing response)

Task

- On-line “who done it?” task
  - Sentences were simple
    - Varied by word order: NVN, VNN, and NNV
    - Nouns were animate or inanimate
    - No intonation cues
  - Words and picture stimuli presented simultaneously on computer screen
  - Child indicates the agent by pointing to the appropriate picture
  - Yields accuracy and reaction time

Stimuli

- NVN-AA The cat kissed the bear.
- NNV-AI The lion the pencil watched.
- VNN-IA Hugged the block the camel.

Typical development results

- 3-4 year olds decide on the basis of animacy
- 5-6 year olds choose first noun in NVN
- 7-8 year olds choose first noun in NVN and second noun in VNN
- 9-10 year olds choose second noun in NNV, adult pattern

(Von Bergen et al, 1996)

First noun choice

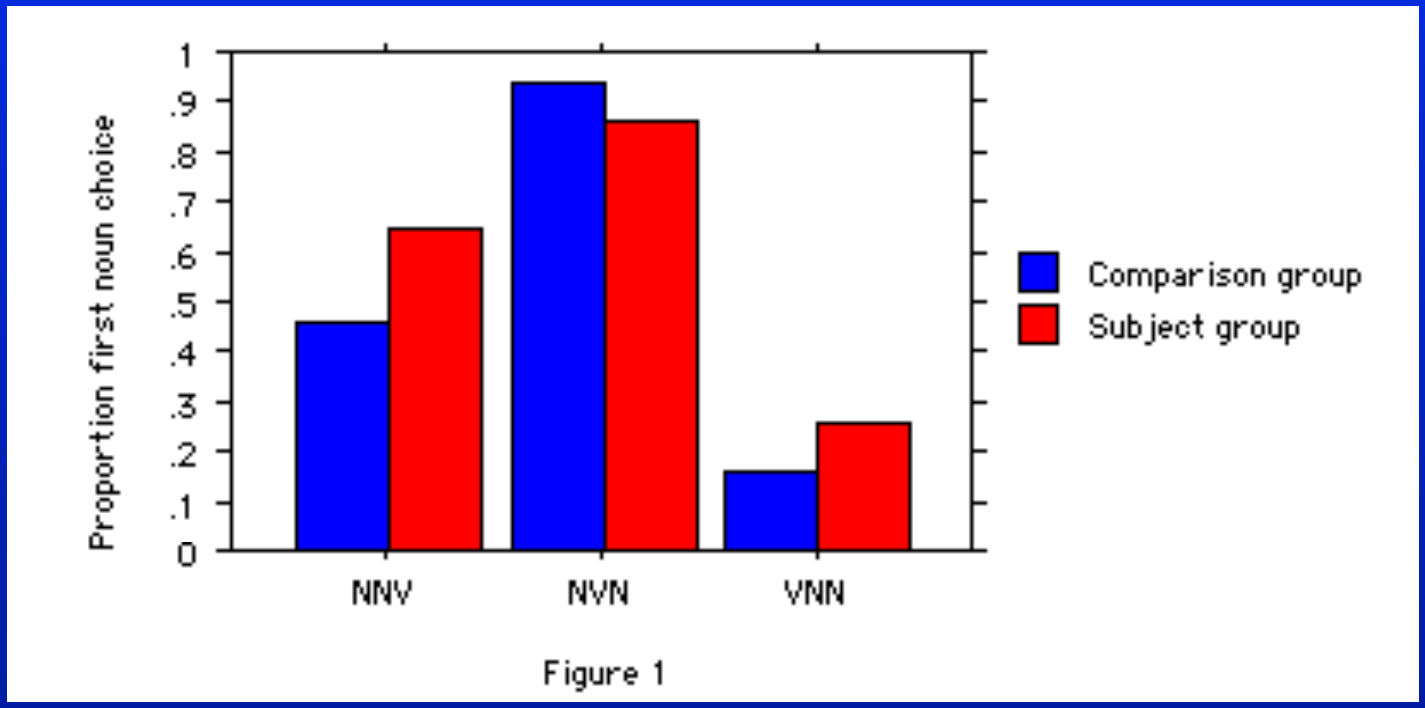


Figure 1

Main effect of word order p<.001
Main effect of group p=.058
Interaction of word order X group p = .027

Reaction Time

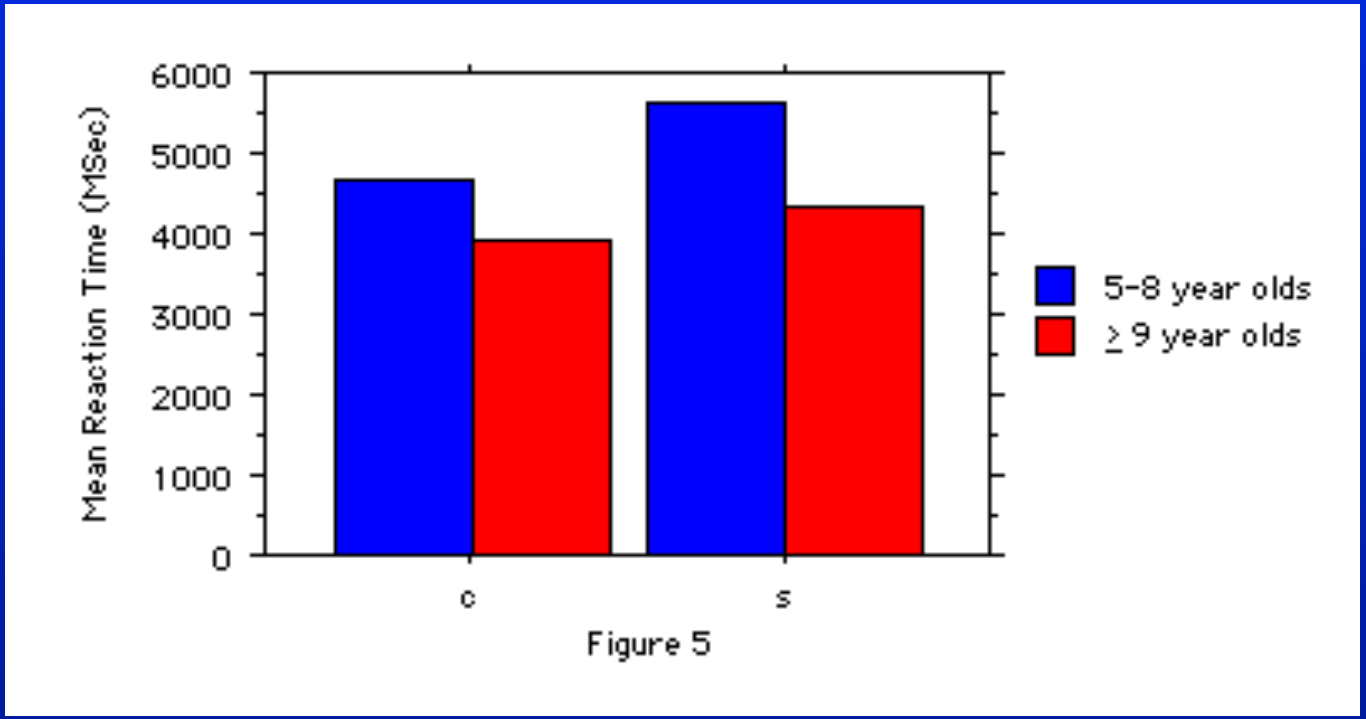


Figure 5

Main effect of word order $p < .001$
Main effect of age $p = .037$

Parameter estimates

	Controls		Subjects	
	Younger (n=82)	Older (n=59)	Younger (n=7)	Older (n=5)
Animacy	.5891	.5782	.5598	.5374
NVN	.9242	.9720	.8131	1.000
VNN	.1955	.0967	.2460	.1891
NNV	.4746	.4428	.6428	.6684

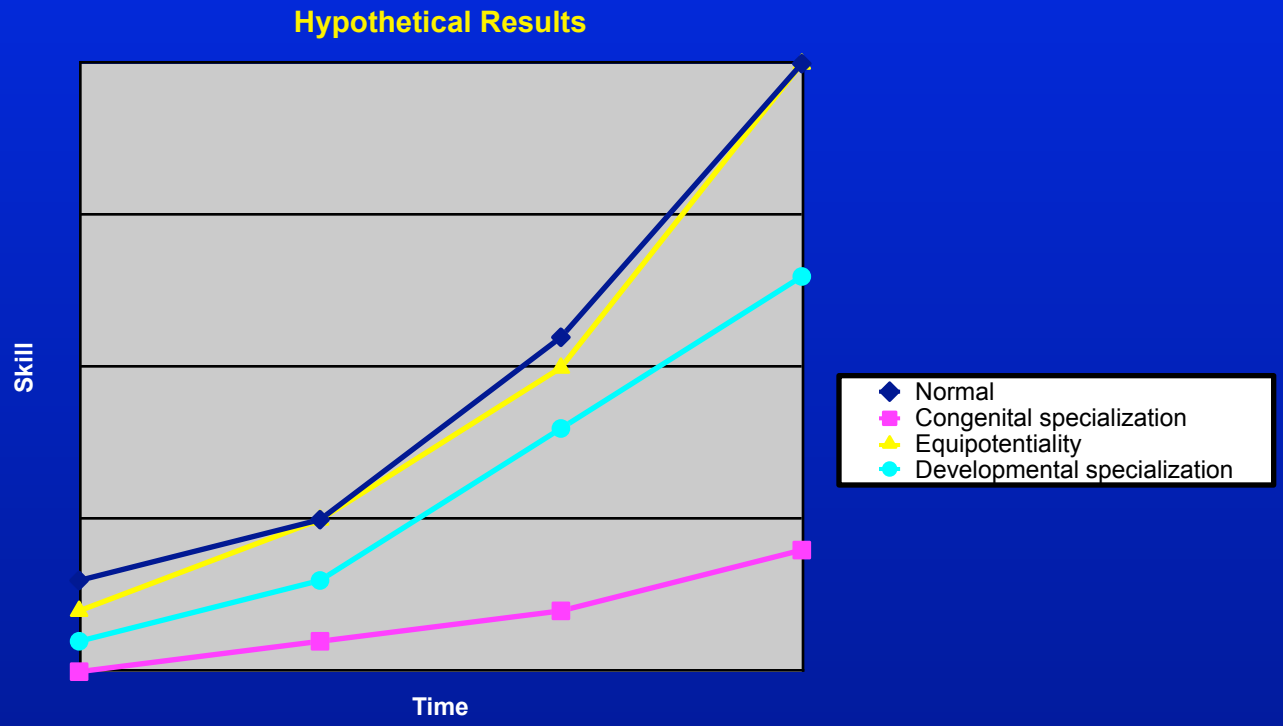
Children with RH damage

- N = 3
- 2 children were delayed
- The only child of the 15 subjects to show mature strategy on the NNV was one with RH PVH

Summary

- Unexpected developmental delays in children with LH and RH brain injuries in sentence comprehension strategies
- Variability in performance across the group
- Would be useful to assess children > age 12 years

Developmental course after early brain injury

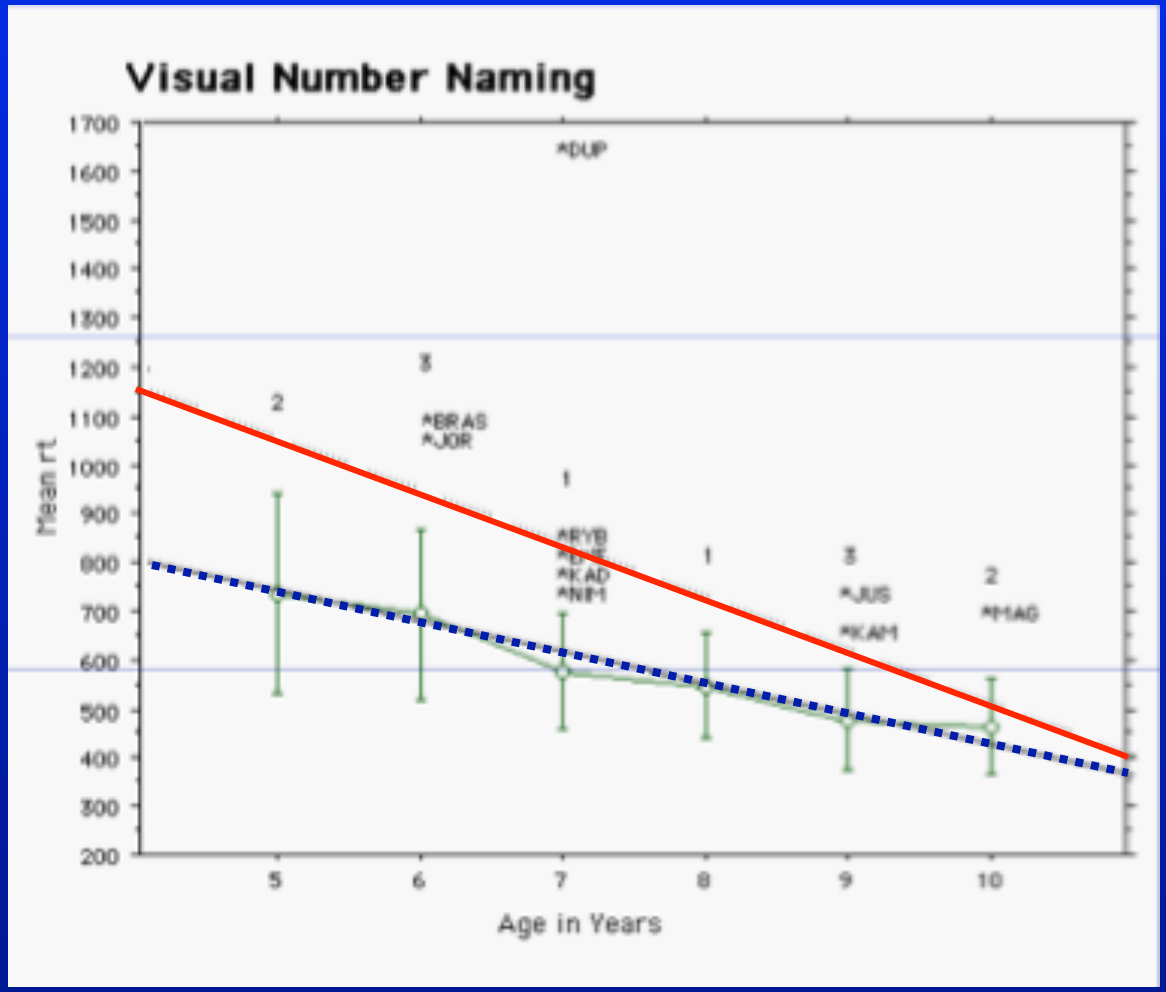


Information processing tasks

(Feldman, MacWhinney, Sacco, Valdez-Perez, 2000)

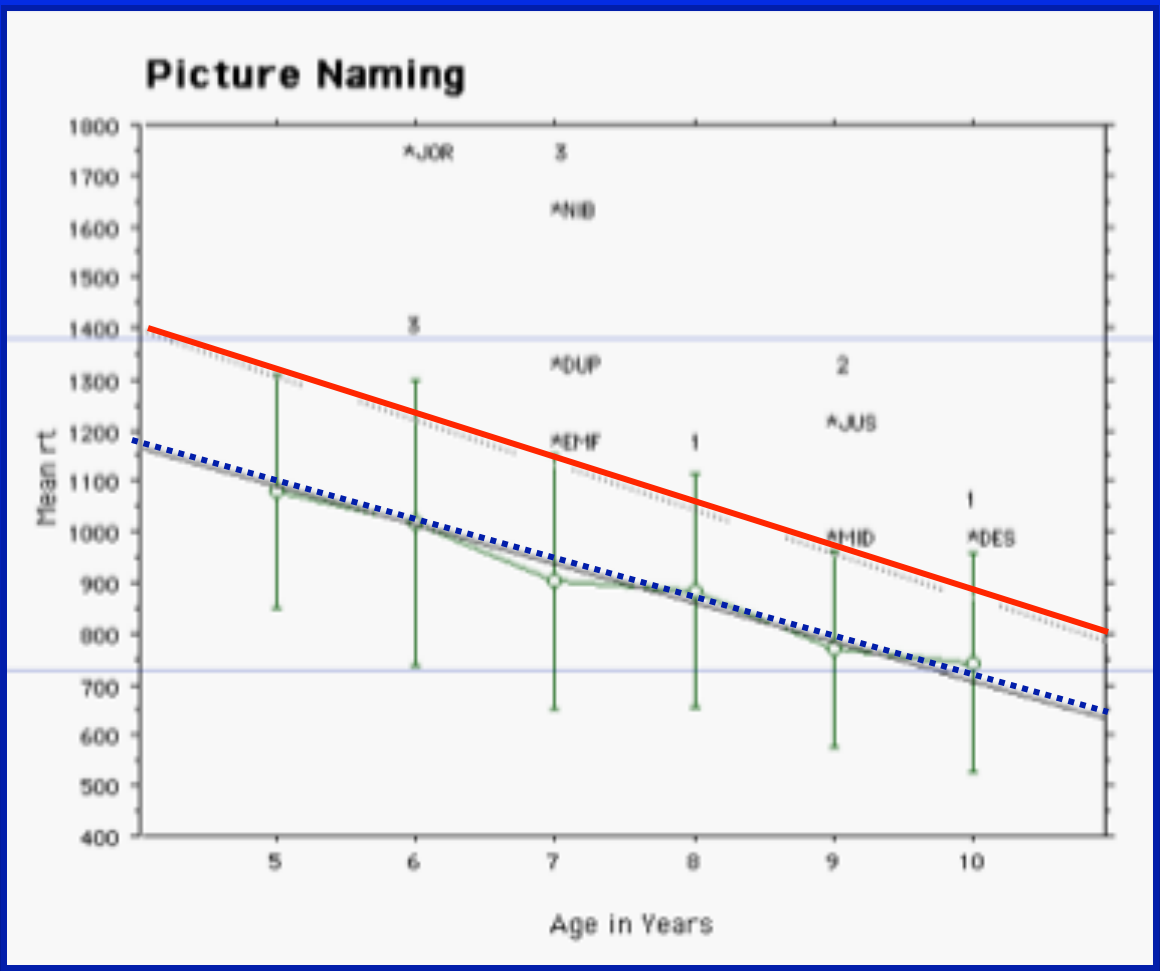
- Goal: to identify specific patterns of impairment as a function of lesion location as source of language and sentence comprehension profiles
- Tasks—computerized tasks
  - Picture naming, number naming, word repetition
  - Also, digit span task
- Measures—accuracy and reaction time
- Data analysis—profiled subjects' scores in comparison to scores to 150 children at appropriate grade for age

Results



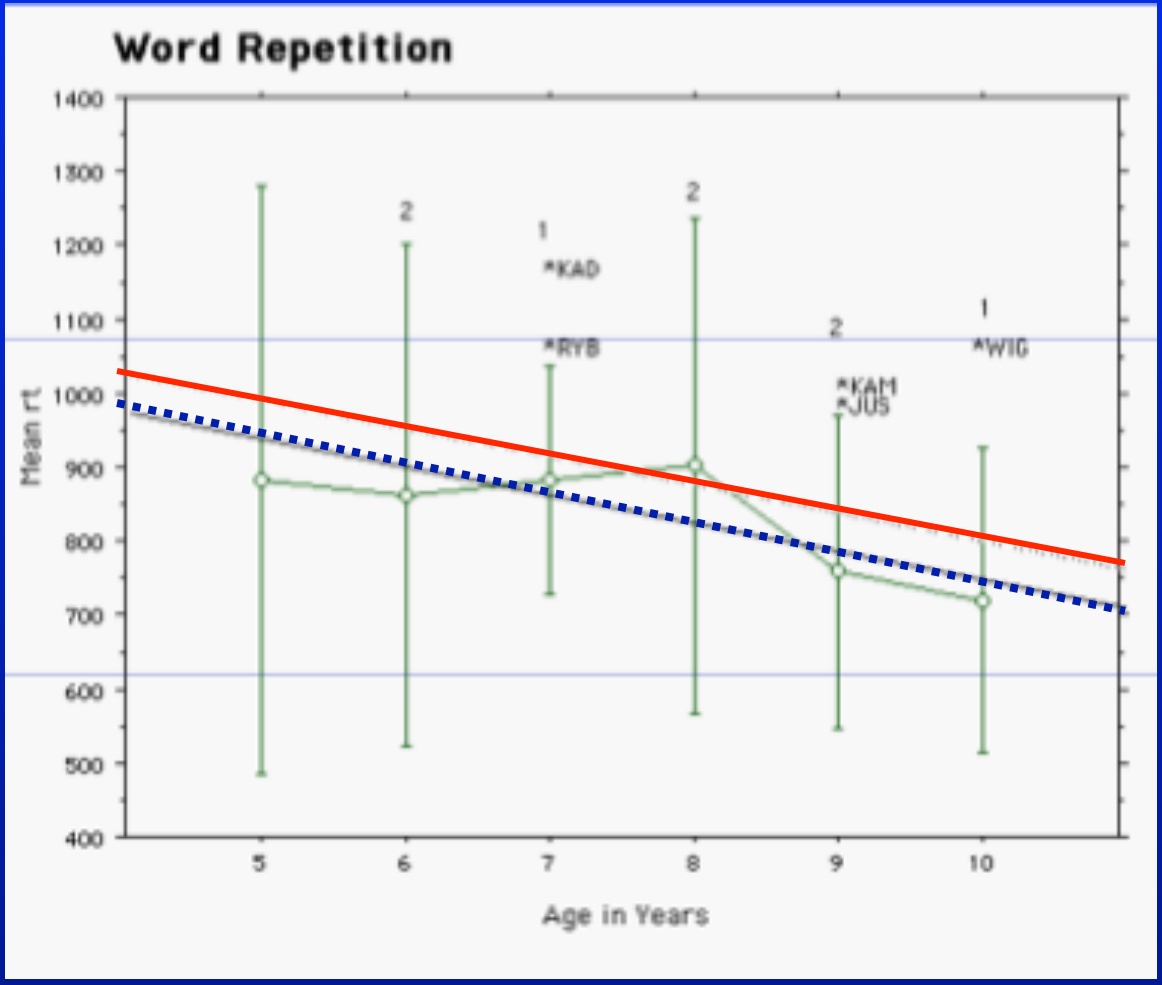
Out of range:
Ss 10/20
Cs 12/150

Results



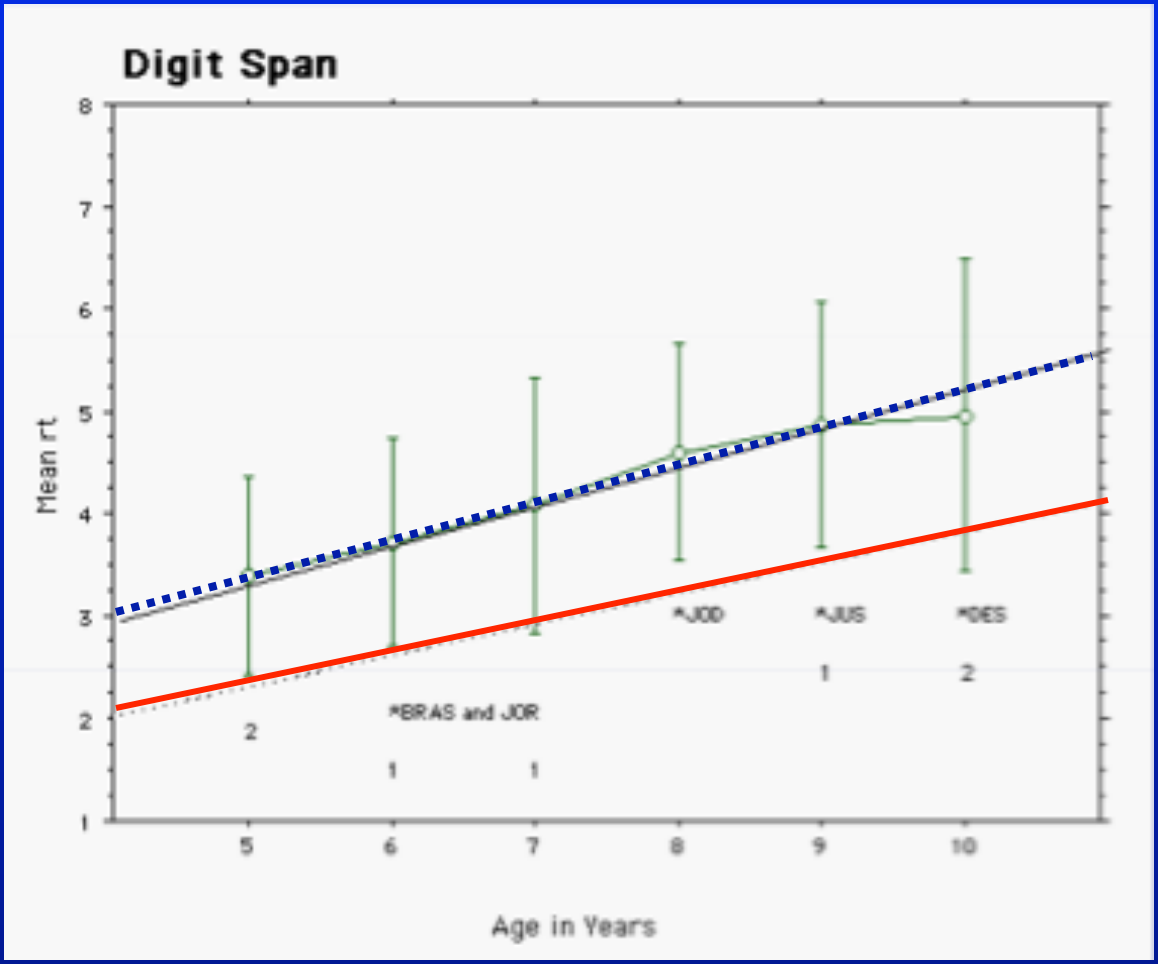
Out of range
Ss 7/20
Cs 10/150

Results



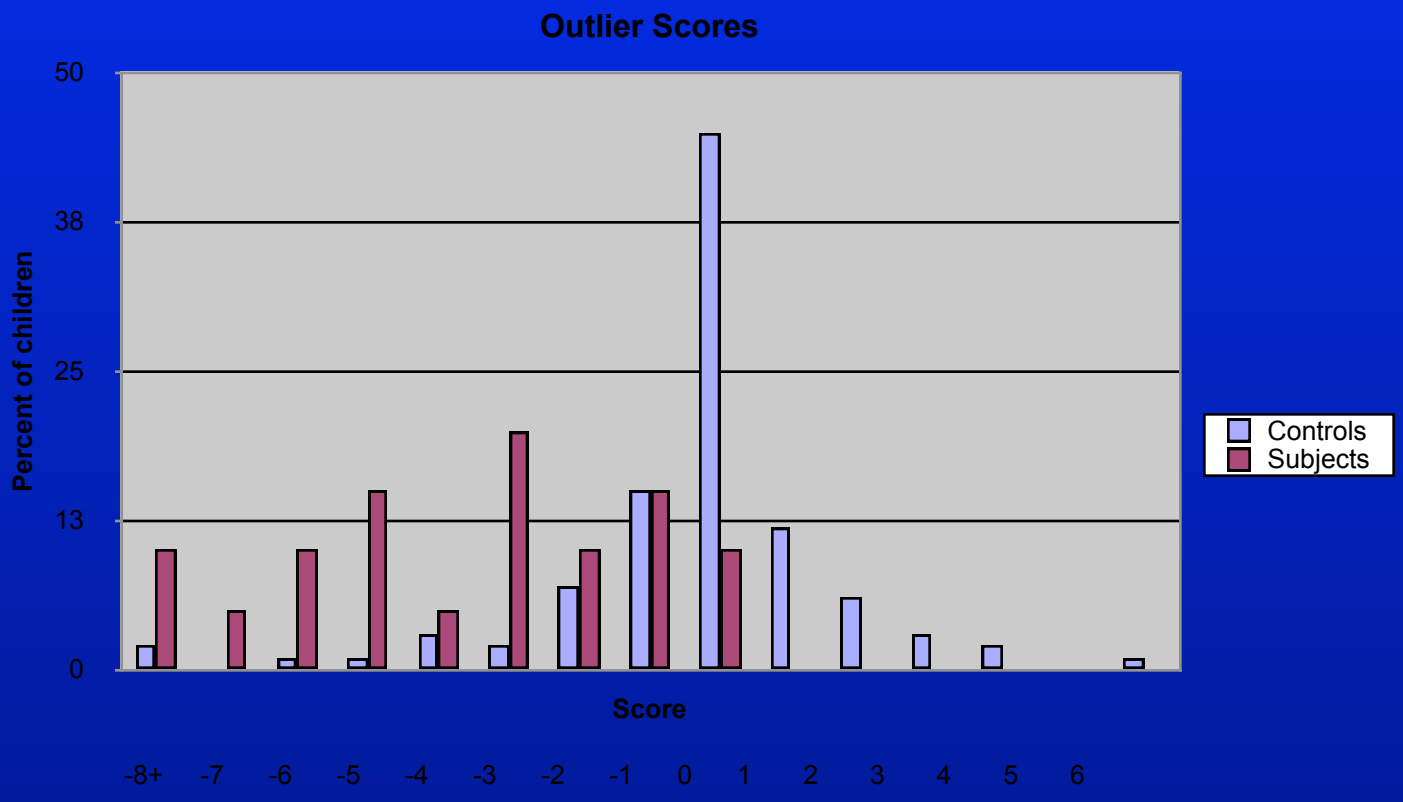
Out of range:
Ss 5/20
Cs 7/150

Results



Out of range
Ss 5/20
Cs 7/150

Children's net outlier scores



Language Sparing

- Focal lesions kids didn't do poorly overall
- All scored within 95% confidence interval from the normal mean on at least half of the tests

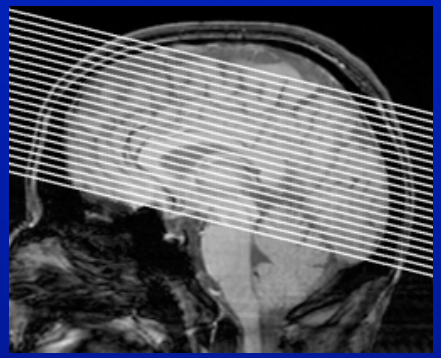
Language Deficit

- Children with the lowest scores were usually the focal lesion kids
- Each focal lesion child had at least one test for which they scored significantly below normal

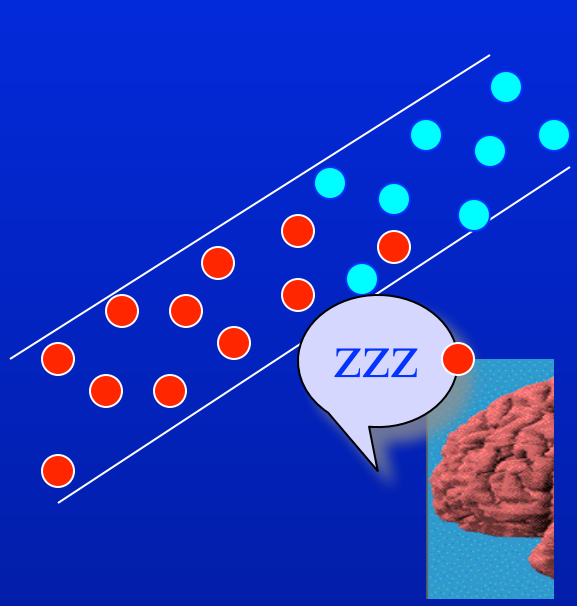
Summary

- No highly specific pattern associated with lesion location
- In general, children with brain injury perform simple information processing tasks more slowly than peers
- Suggestion that children with LHD have selective difficulty in naming
- Need for larger sample and more language-related tasks

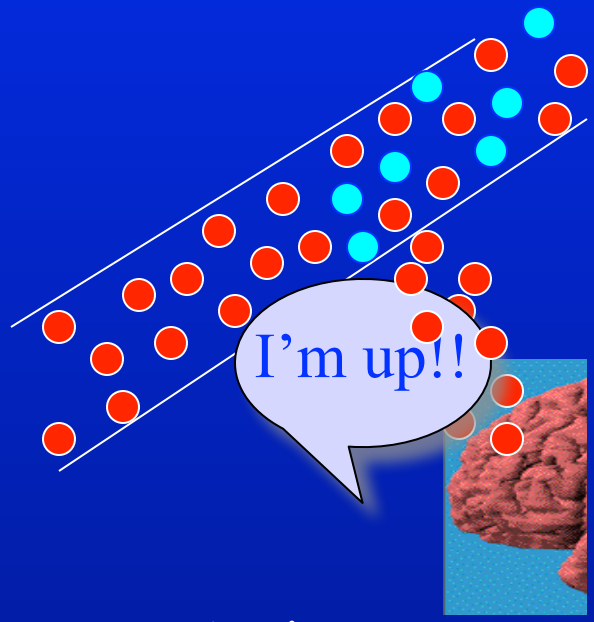
How is the brain organized to



fMRI: assesses function through hemodynamic consequences



Inactive state



Active state

Uses of fMRI

- Basic question: Where is a specific operation performed in the brain?
- Measures
  - Identity of brain regions involved: Region of interest
  - Magnitude of activity in those regions
  - Spatial extent of activation
  - Correlations among activity in brain regions

Brain activation during sentence comprehension

- Goals:
  - Describe developmental differences in brain activation during sentence comprehension
  - Describe functional organization of sentence processing in children with early brain injury
- Hypotheses:
  - LH activation in adults and children
  - RH activation in children with LHD

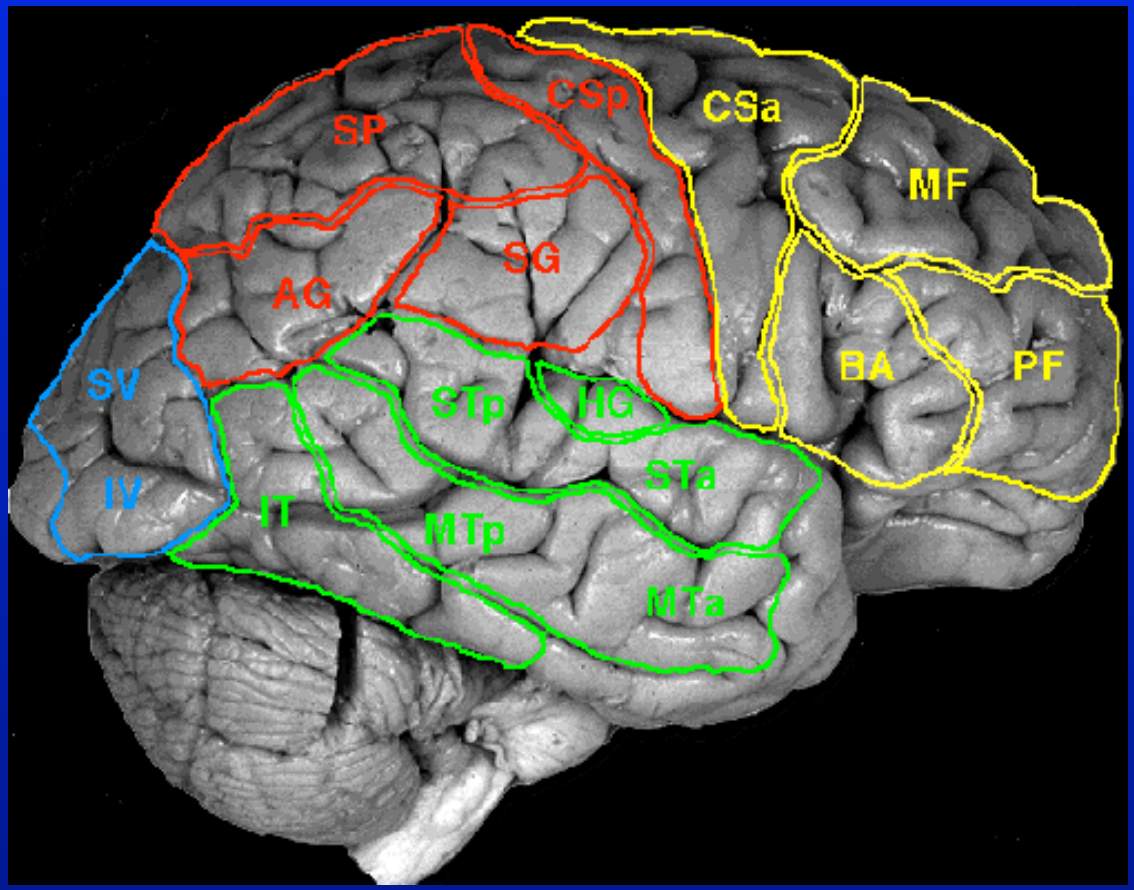
Methods

- Subjects
  - A: 20-28 year old right handed (n=5)
  - C-NN: 9-12 year old right-handed (n=7)
  - C-BI: 9-12 year old (n=6)
    - 3 LH stroke
    - 2 LH periventricular hemorrhage
    - 1 RH stroke

Sentence comprehension task

- Auditory presentation of 3 sentence types
  - CVP: The cat chased the rabbit and enjoyed the hunt.
  - SR: The principal that tripped the janitor used the phone to call home.
  - OR: The pig that the dog followed ate the trash in the street.
- Comprehension test after each presentation
  - T/F: The principal used the phone to call home. (T)
  - T/F: The dog ate the trash in the street. (F)

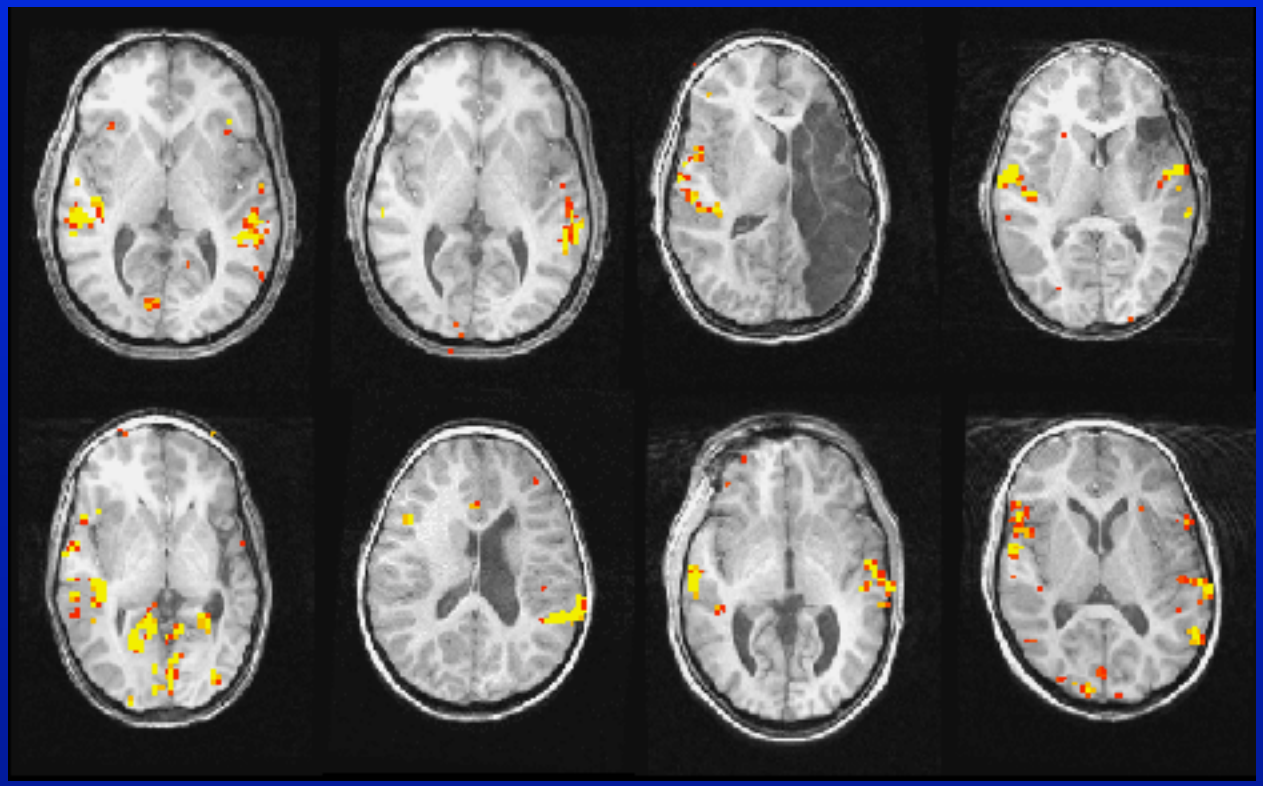
Analysis: 17 ROI



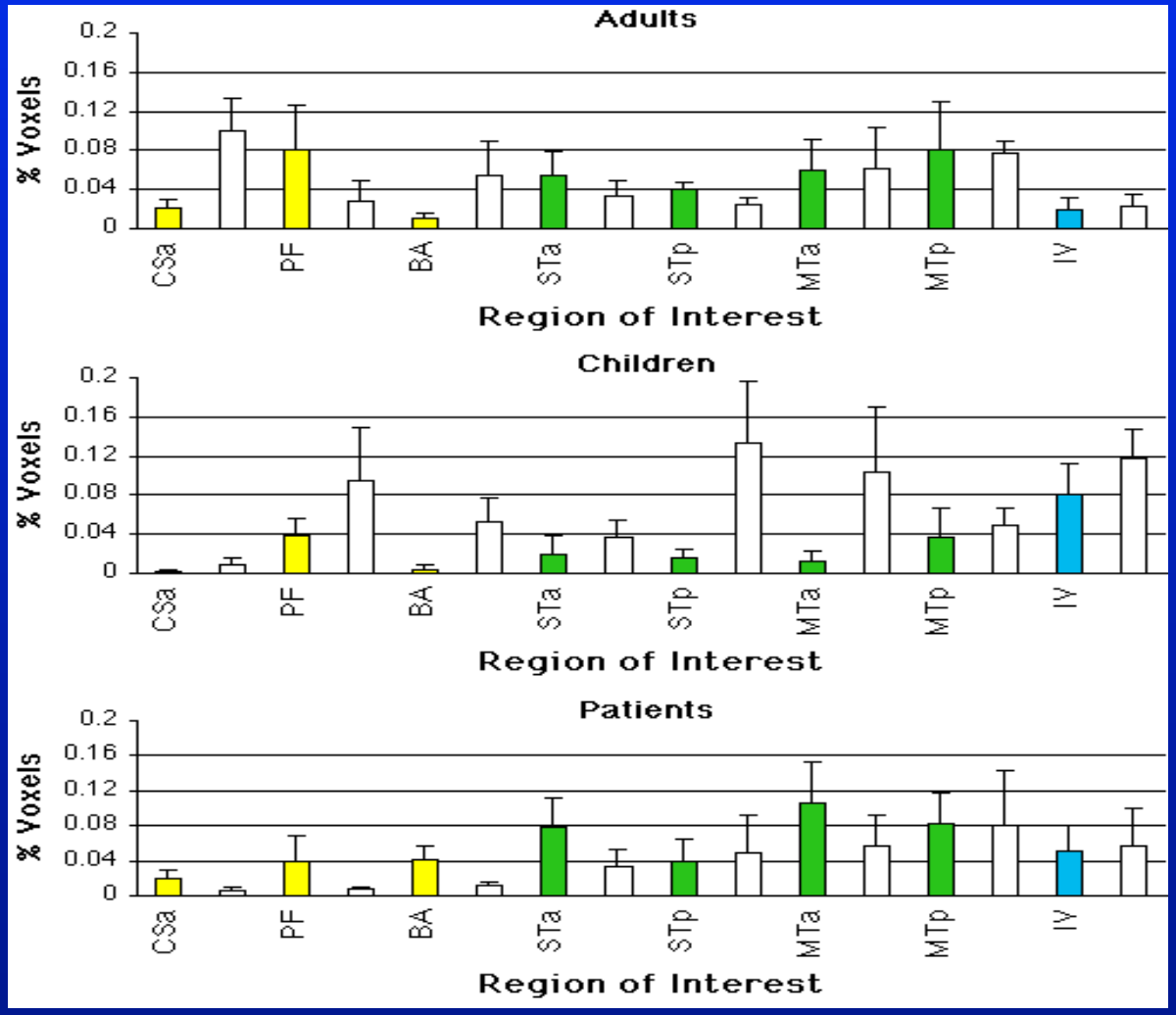
Results: Percent errors

	Sentence Types		
Participants	CVP	SR	OR
Adults	11%	7%	18%
Children	36%	32%	36%
Children with brain injury	42%	51%	42%

Results sentence processing

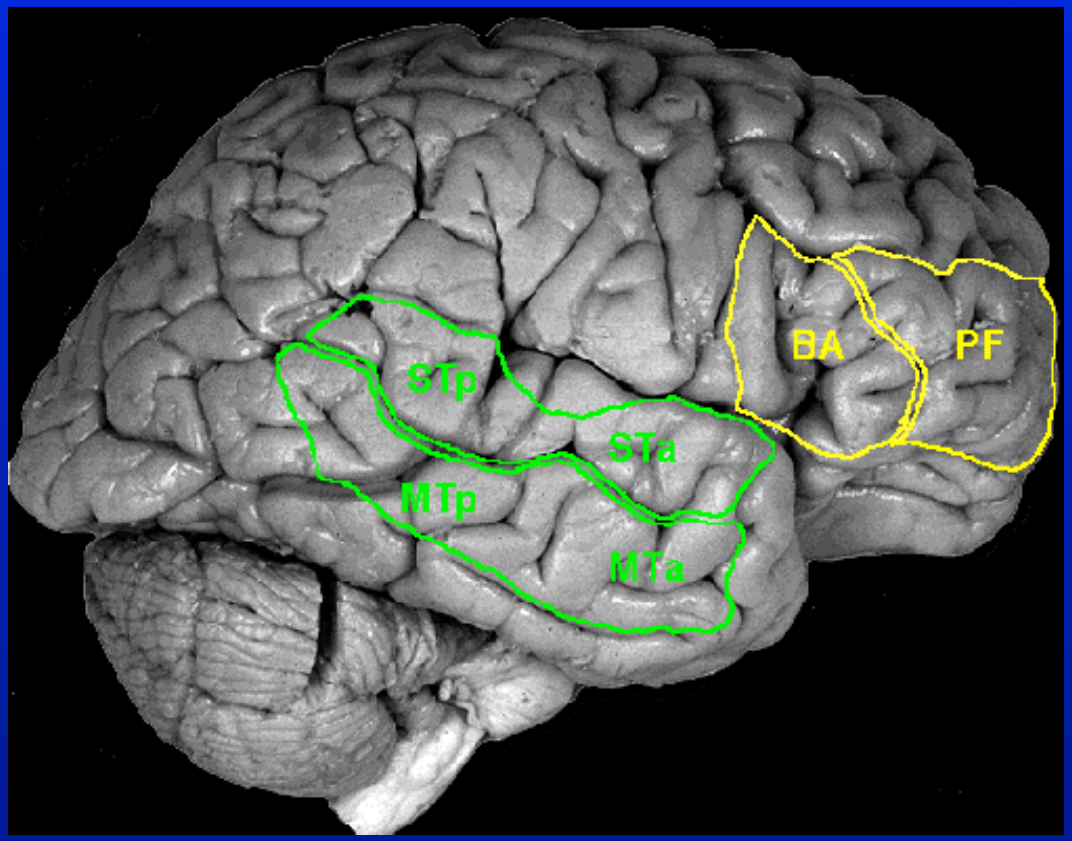


Results by ROI



Colored bars RH
Open bars LH

Network for sentence comprehension



Summary

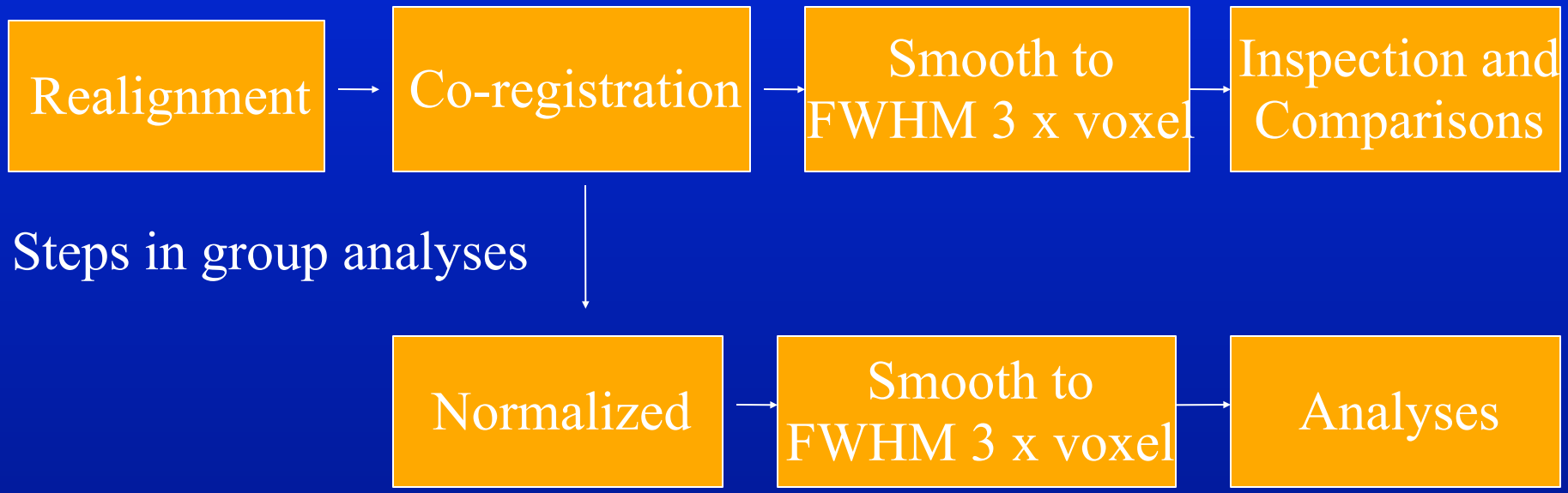
- Activation patterns for sentence comprehension show developmental change
  - Greater levels of activation in adults
  - Bilateral activation in adults
- Children with brain injuries show more errors than do children and adults
- Children with LH injuries show shift to increased RH activations

Verb generation and mental rotation

- Verb generation
  - Presentation of pictures of common objects
  - Instruction: “Say to yourself as many actions as you can do to or with each object presented”
- Mental rotation
  - Presentation of 2,G at 0^0, 135^0, 180^0, and 225^0
  - Decision about direction of letter/number
- Rest for both conditions
    - Presentation of cross

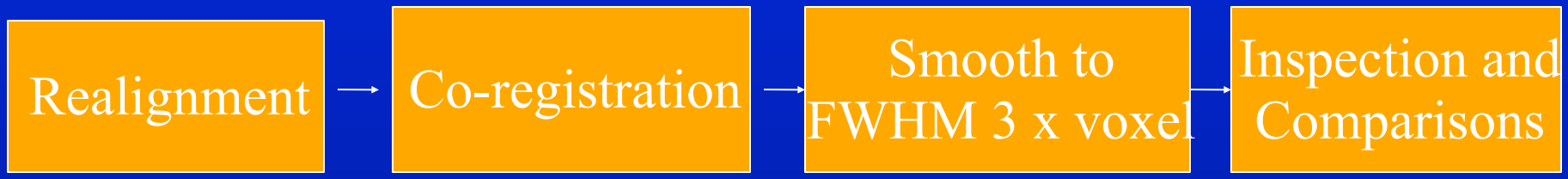
Post-acquisition SPM99 processing: Adult and Children groups

Steps in individual Analyses

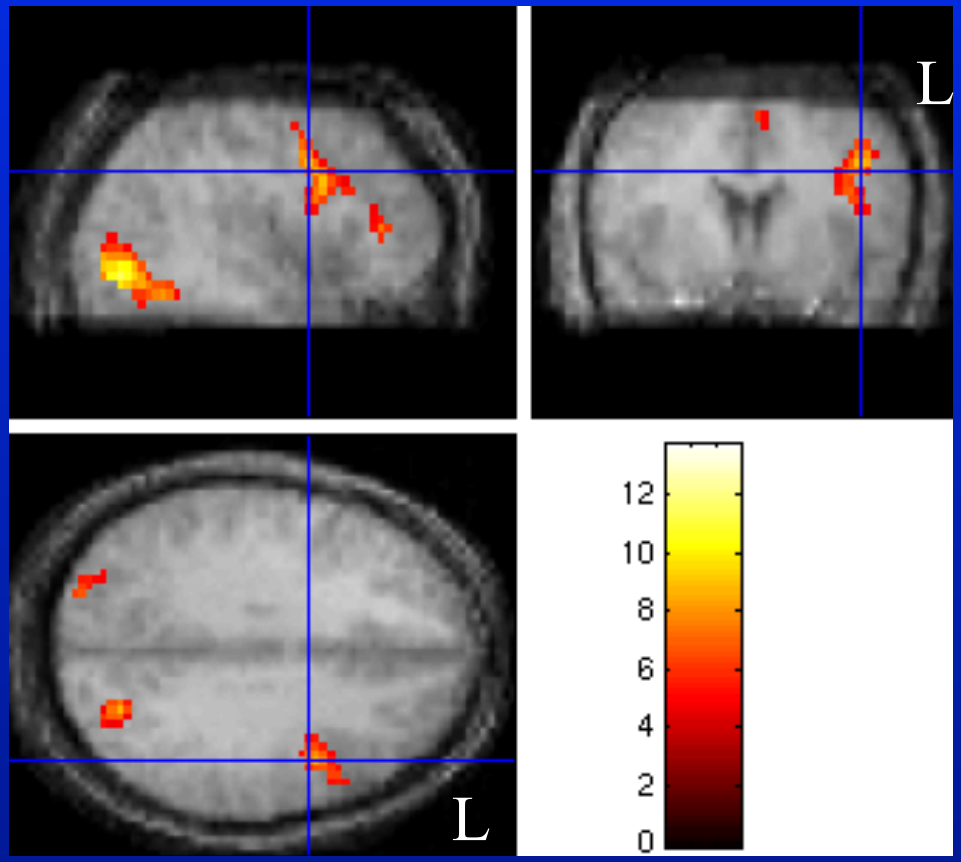


Post-acquisition processing – Children-BI

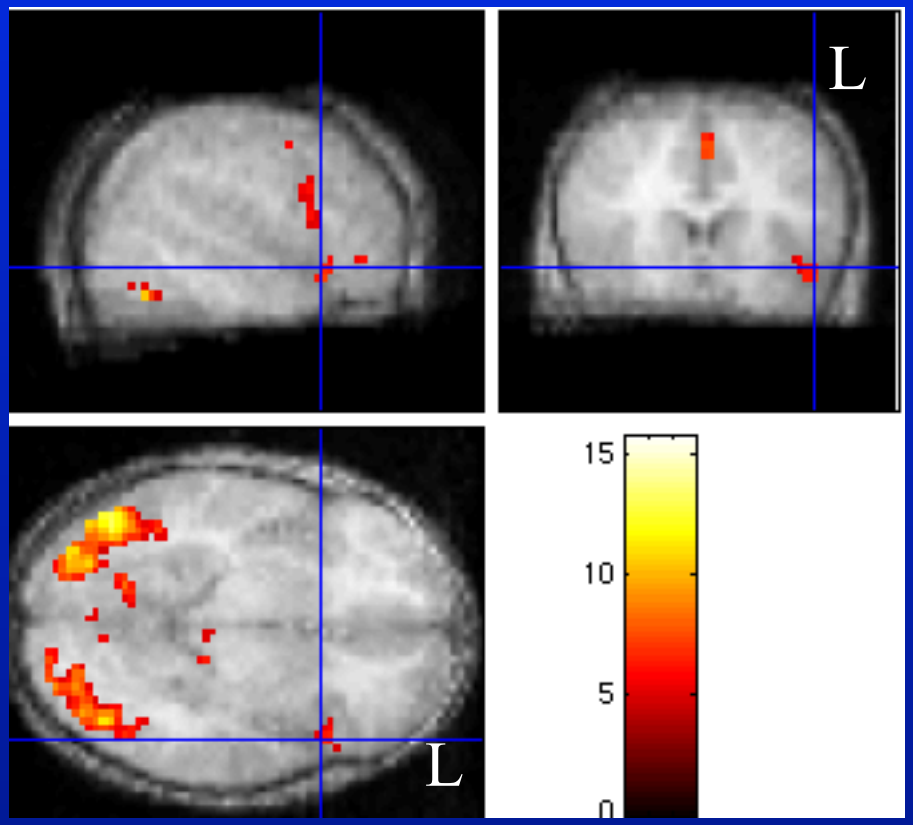
Case study approach



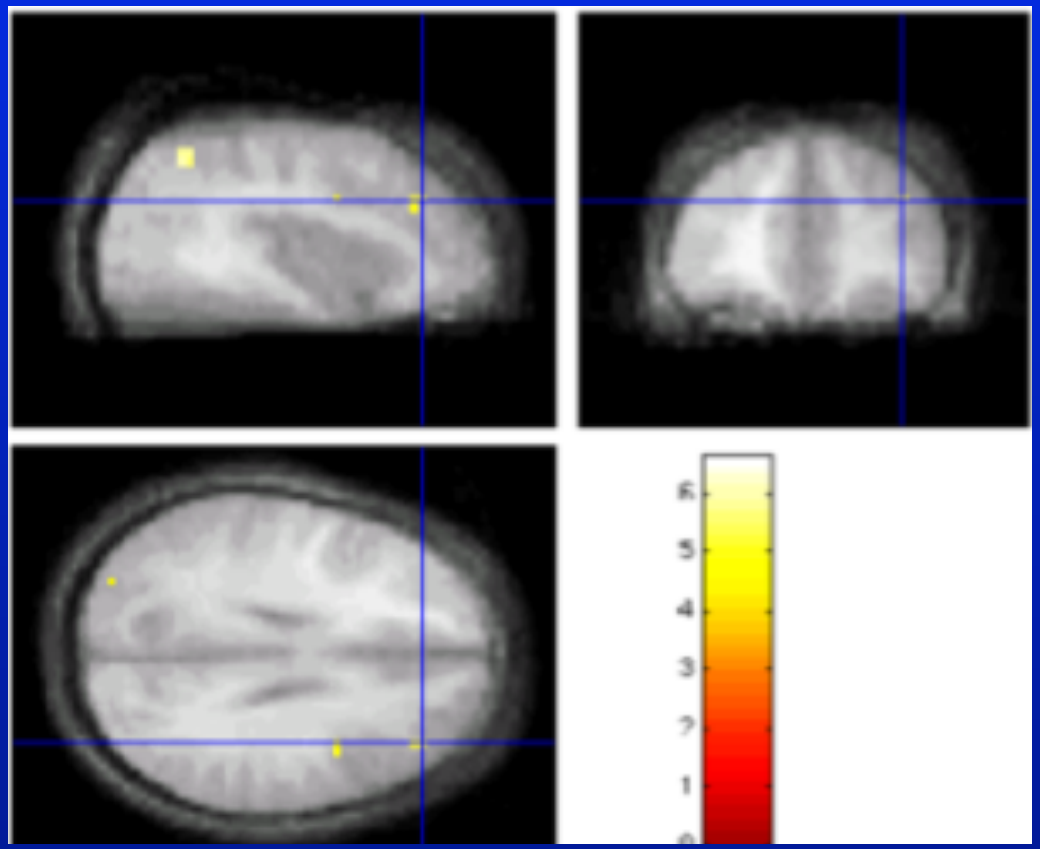
Verb generation - adults



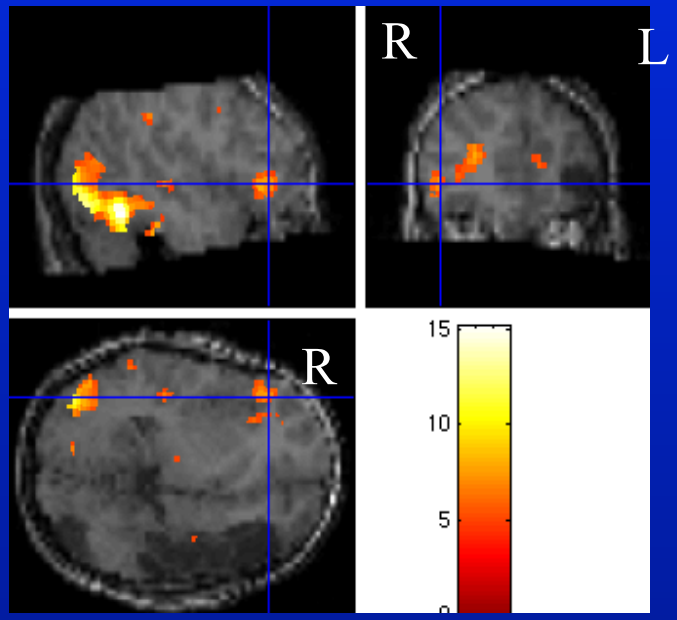
Verb generation -- children

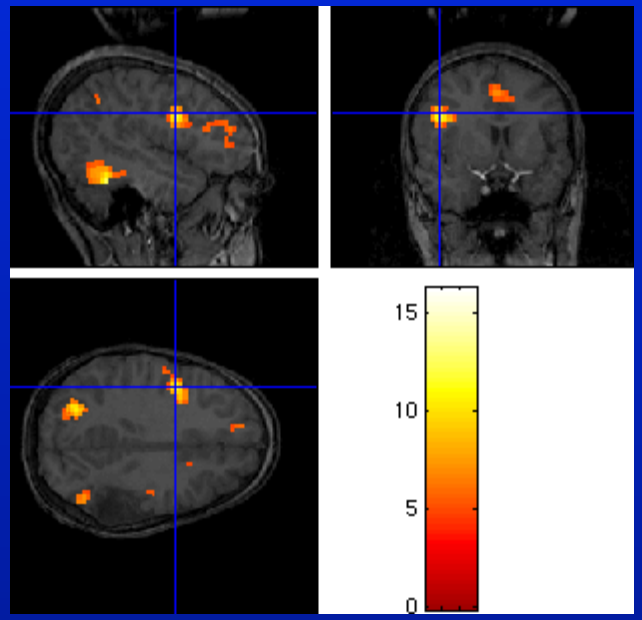


Adults minus children

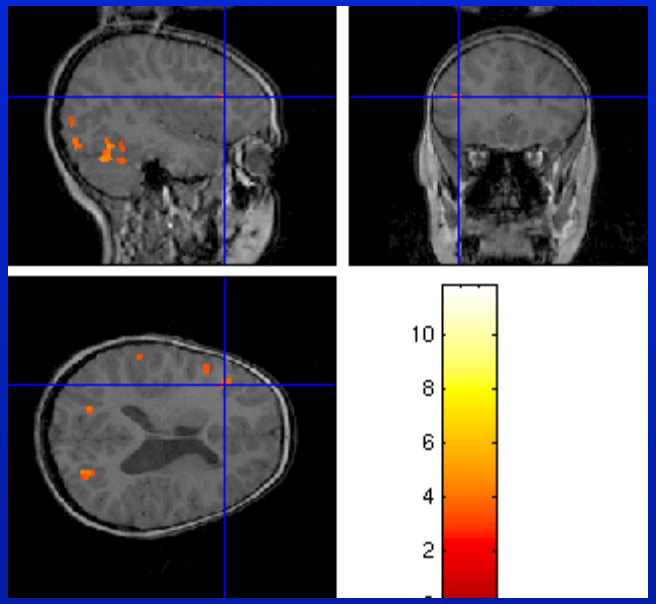


Verb generation—children with LH stroke

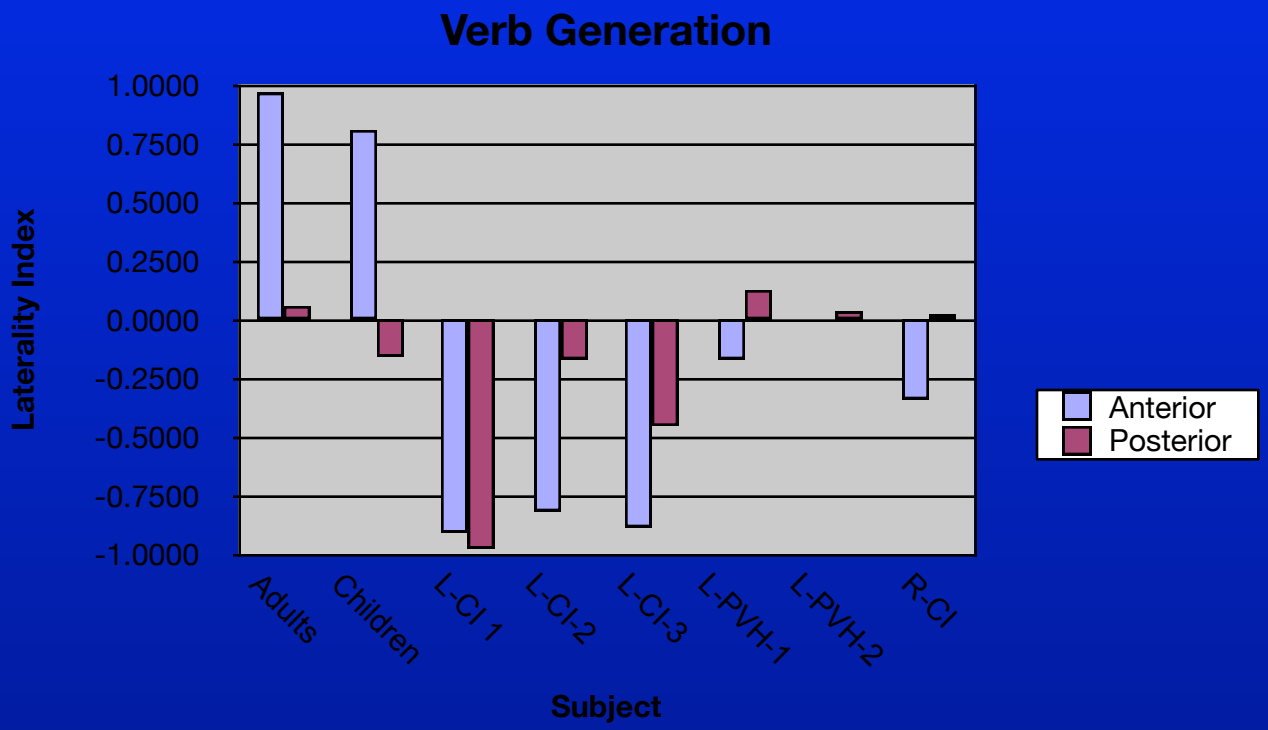




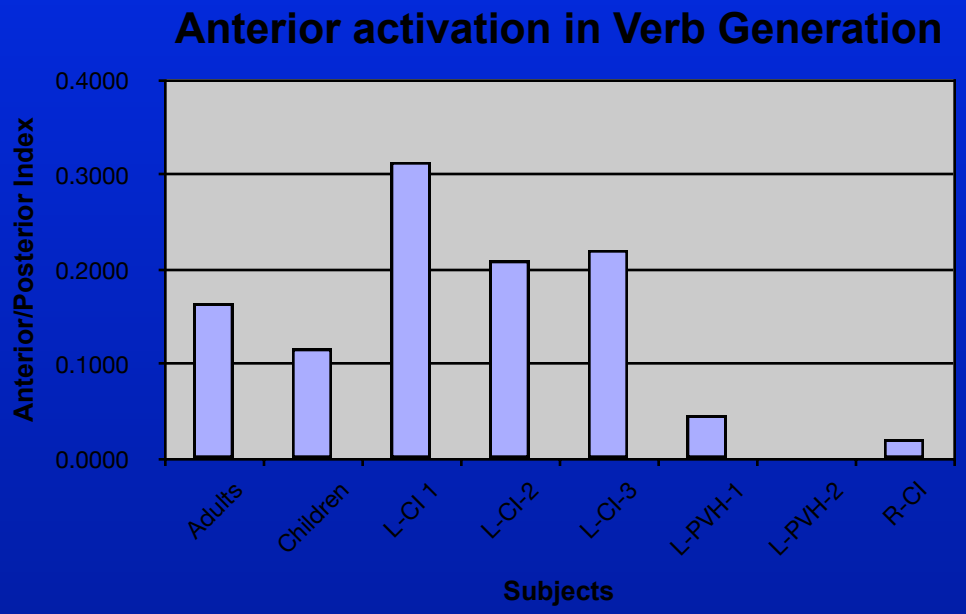
Verb generation – children with L-PVH



Laterality index

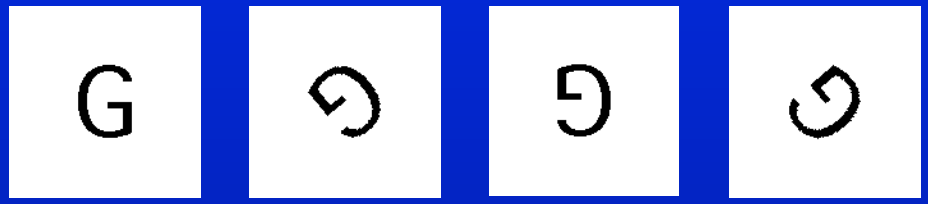


Proportion of anterior activation

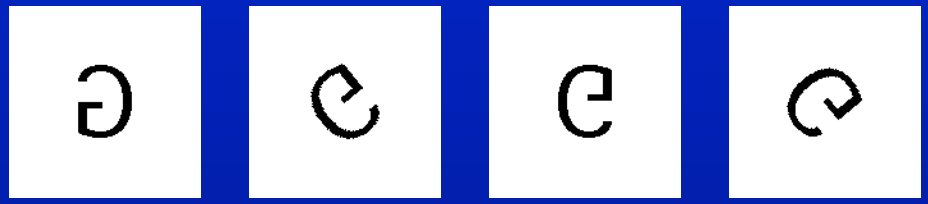


Mental Rotation Stimuli

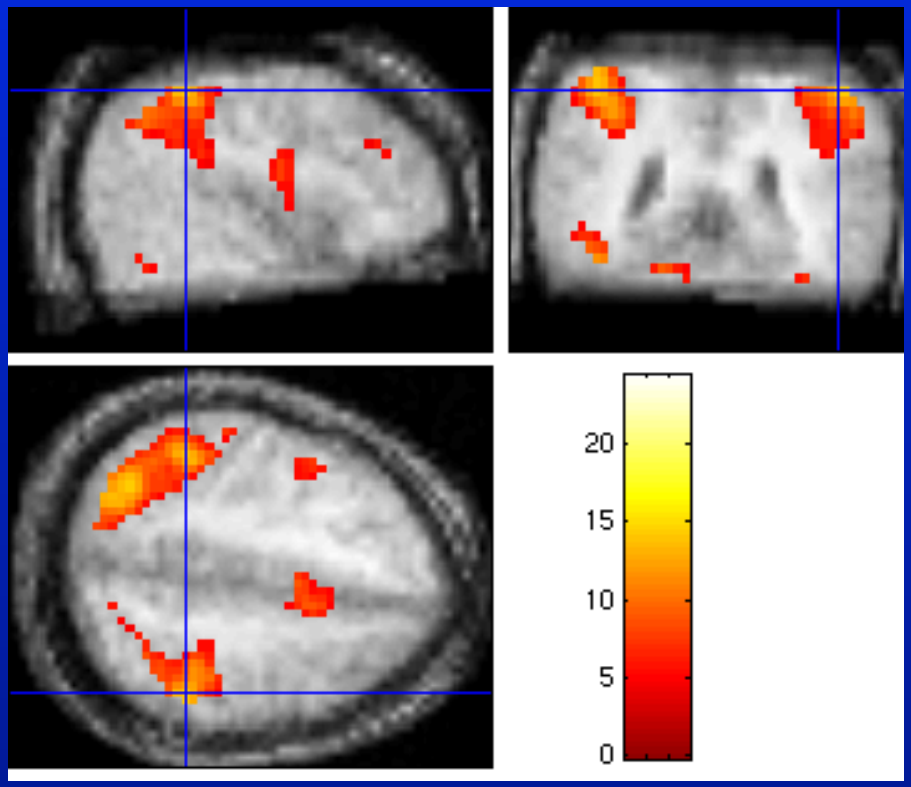
Targets



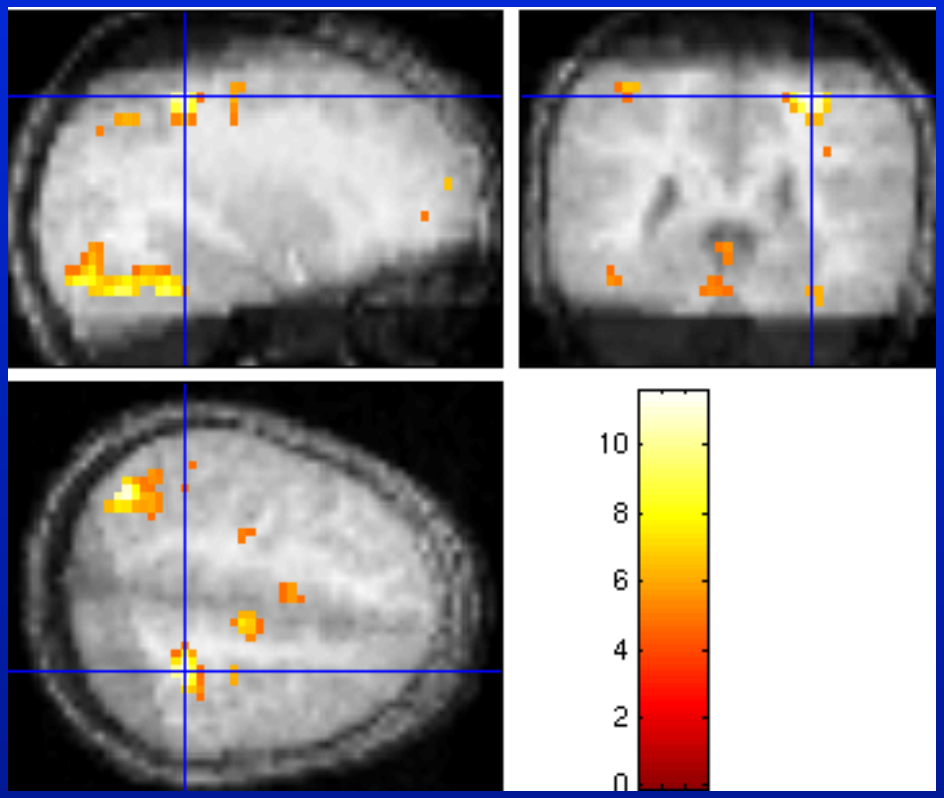
Distractors



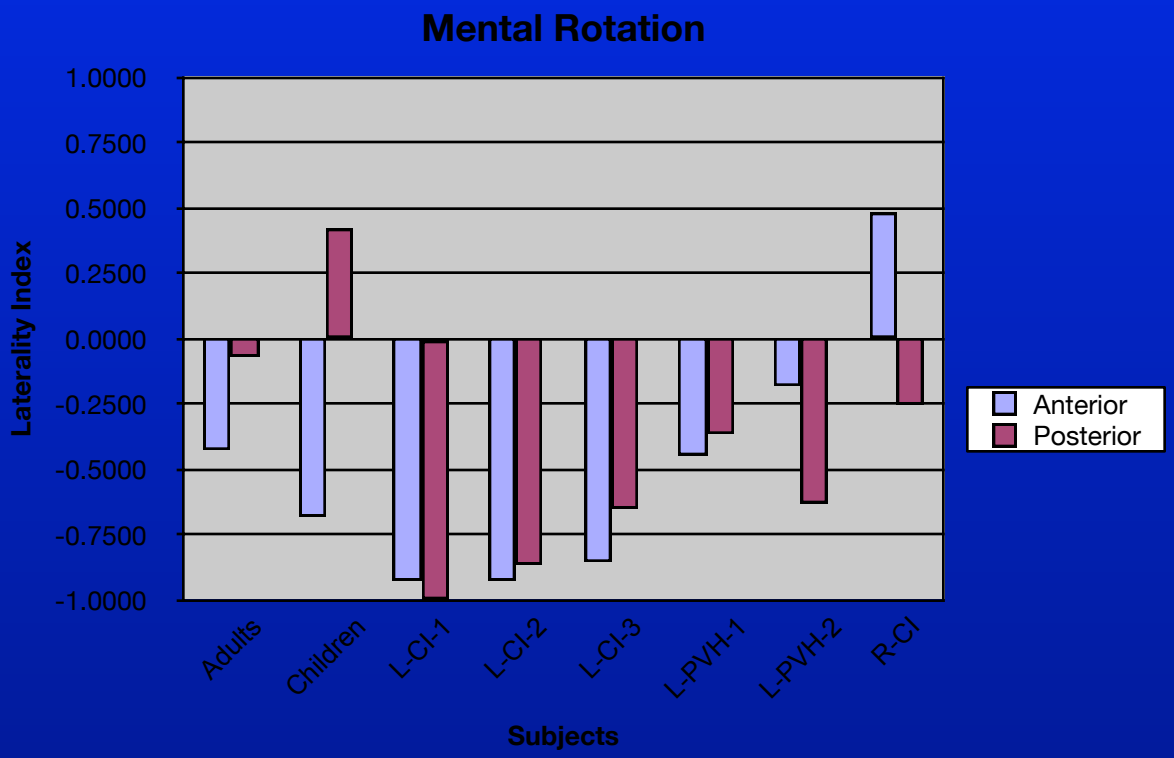
Mental rotation - adults



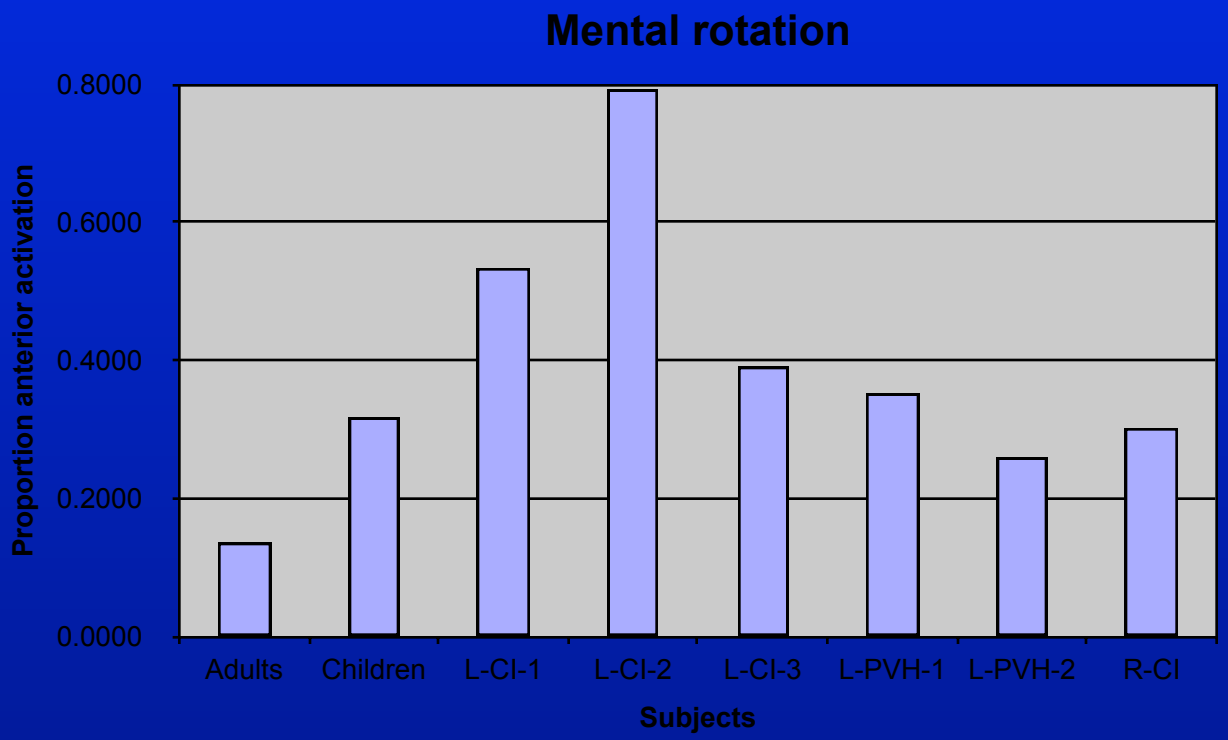
Mental rotation -- children



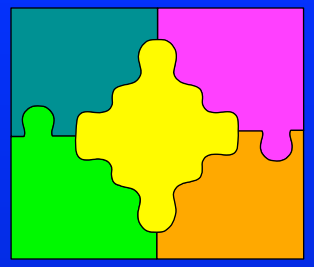
Laterality index



Proportion of anterior activation



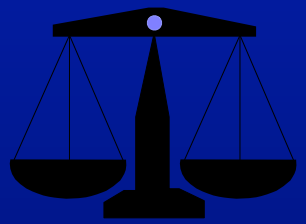
Overall summary



- Development of children with early brain injury favors developmental specialization view; language areas not completely predetermined
- Integrity of the entire brain supports launching language development
  - Children with RH damage often show initial delays
  - Consistent with ERP data (Mills and Neville)
  - RH remains available for language tasks under normal circumstances
  - RH can serve language if LH damaged
  - Effects of reorganized language minimally apparent in functional tasks such as conversation

Summary

- Alternate brain organizations may not be as effective as typical brain organizations for language processing
  - Children with brain injuries have lower scores on formal testing
  - Children with brain injuries have subtle delays under demanding circumstances
  - Children with brain injuries are slower at information processing



Summary

- fMRI suggests intriguing possibility of multiple reorganization patterns
  - L stroke had strong R anterior activations
  - L PVH had R laterality but minimal anterior activation
  - All may result in information processing inefficiencies
- Calls for systematic, larger imaging study
  - Correlations with behavioral data
  - Variations as a function of lesion, age, and performance level

Thank you.