Theoretical perspectives on impairments in spoken language processing

- Goal: foster greater collaboration between theoretical research on language processing and research on impairments of spoken language processing.
- Speakers: Experts on impairments of spoken language processing
- Thanks for partial funding to the Neuro-Cognitive Rehabilitation Research Network (www.ncrrn.org), which provides research infrastructure support and expert consultation to individuals interested in pursuing cognitive rehabilitation research

Response selectivity and aphasic spoken word recognition

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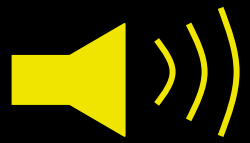
Aphasia

- Impairment of spoken language processing due to brain damage
- Traditional subtypes
  - Broca's: generally anterior lesions (esp. IFG)
  - Wernicke's: generally posterior lesions, primarily affecting temporal lobe (MTG, STG)
- Theories of aphasic lexical processing deficits
  1. Level of activation: reduced for Broca's, increased for Wernicke's (Blumstein, Milberg and colleagues)
  2. Time course of activation: Reduced rate of activation for Broca's, reduced rate of deactivation of competitors for Wernicke's (Prather, Swinney and colleagues)
  3. Reduced short-term/working memory (R. Martin, N. Martin and colleagues)
  4. Perceptual impairment (e.g., Caplan et al., 1995)
  5. Impaired selection among competing alternatives due to IFG damage (Thompson-Schill and colleagues)

Aphasic Lexical Processing: Traditional Experimental Method

What about the underlying dynamics?

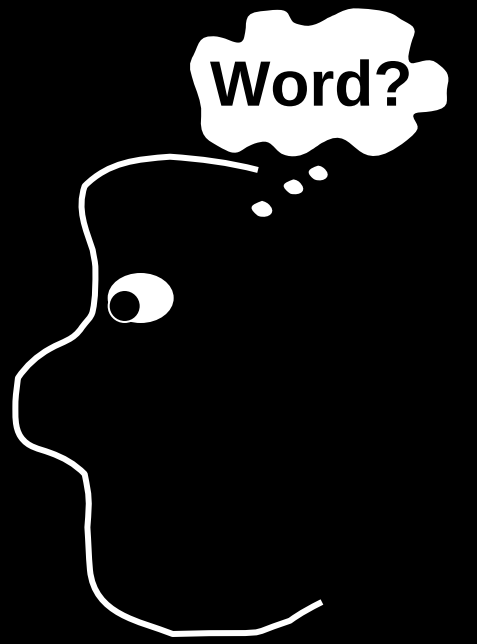


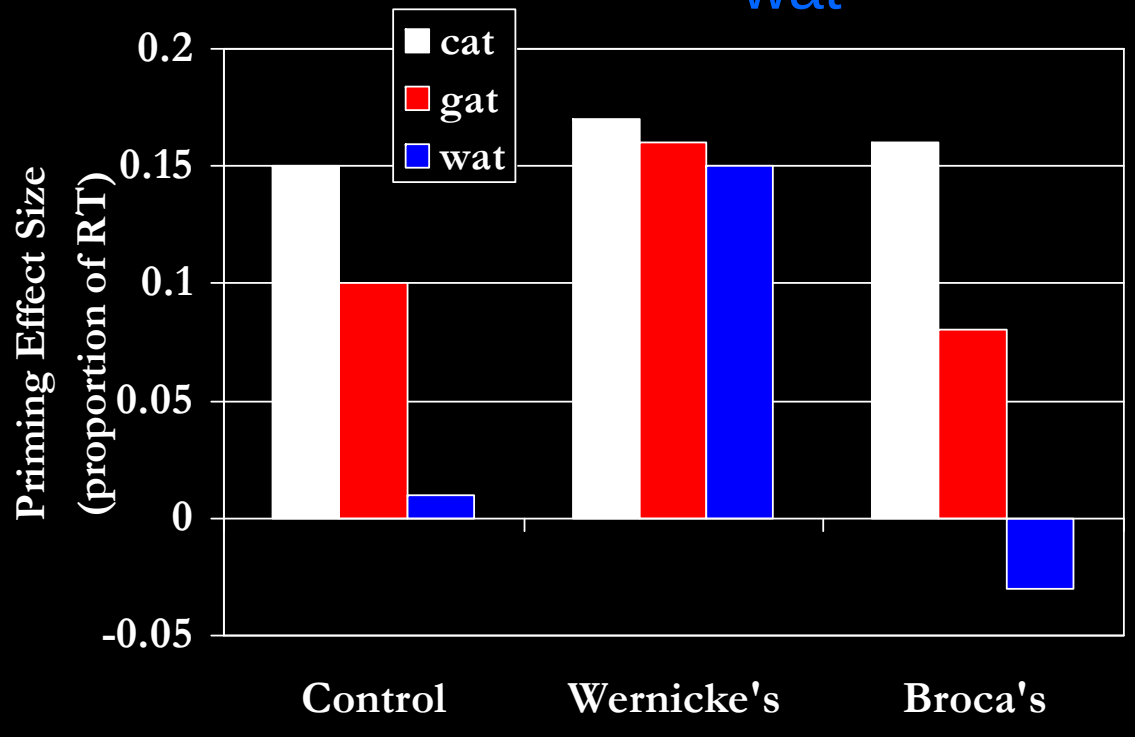
cat

gat

wat

DOG

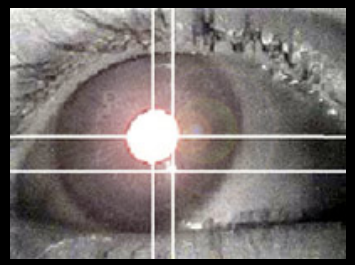




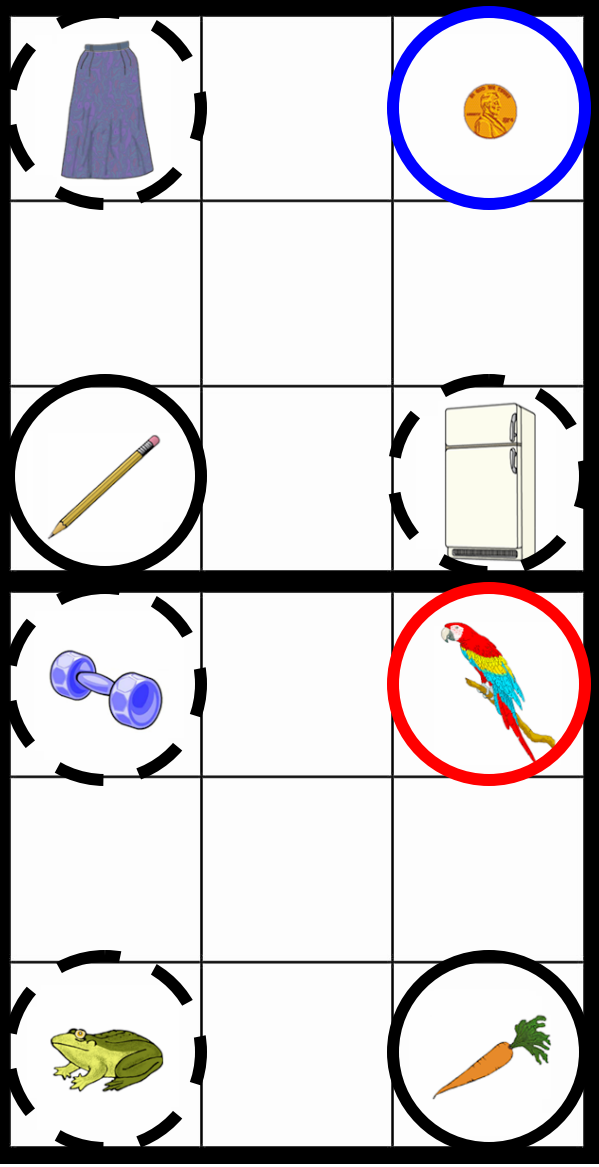
Visual World Eye-Tracking Paradigm

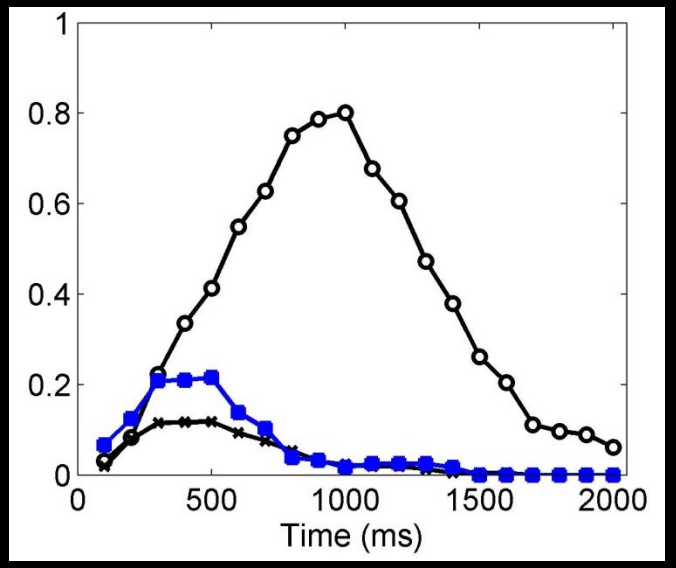
(Allopenna et al., 1998; Yee et al., 2008; and many others)

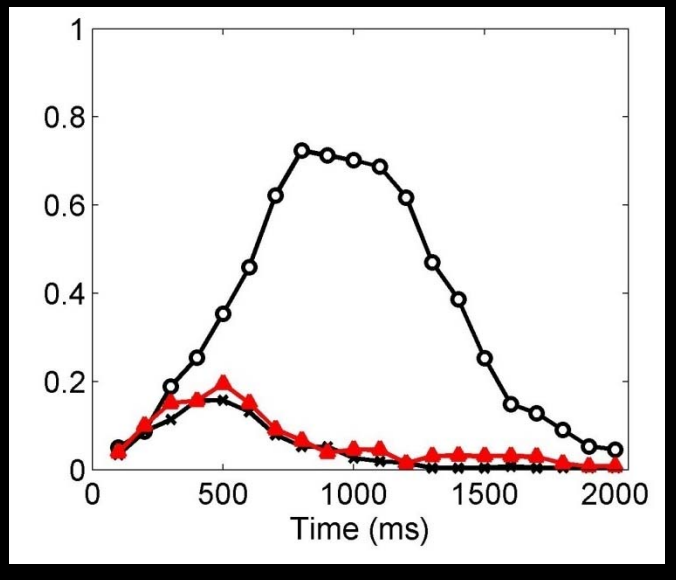
"pencil"



"carrot"







Growth Curve Analysis

(Mirman et al., 2008, *J. Mem. & Lang.*)

- Closely related to Hierarchical Linear Modeling
- Developed for longitudinal results, we just changed the time scale
- Fit the entire time course with polynomial regression model
- Examine effects of factors on polynomial terms

Aphasic Patients

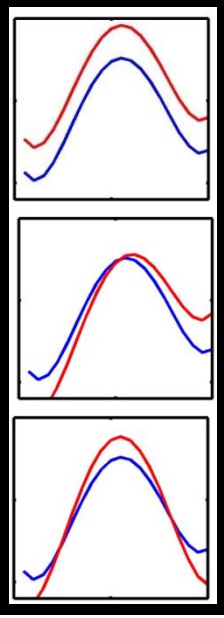
Participants (Yee et al., 2008; Yee, 2005)

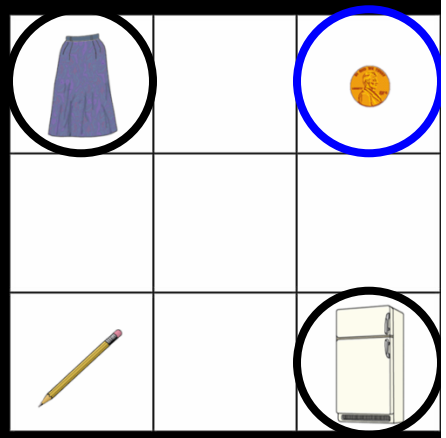
- 5 Broca's aphasics
- 3 Wernicke's aphasics
- 12 Age-matched controls

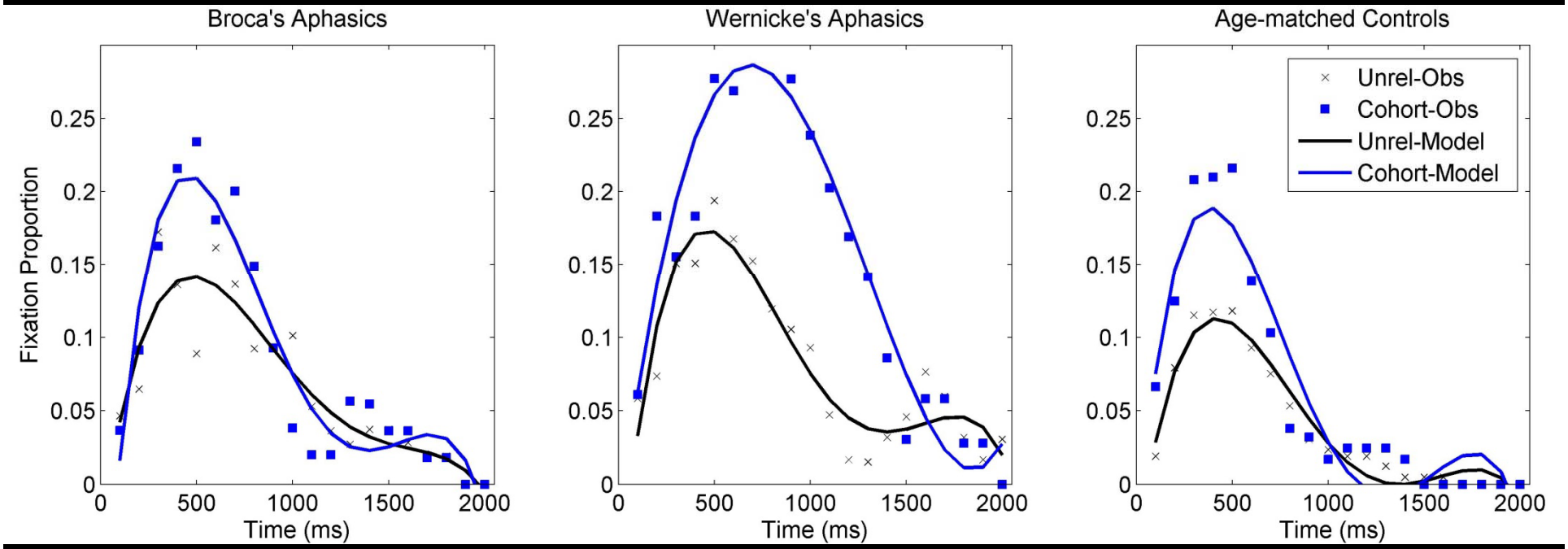
Patient info

- Diagnosed by BDAE
- Several years post-stroke (3-18)
- Mean age: 67 years (44-75)
- English as native language
- Normal hearing and vision (or corrected-to-normal)

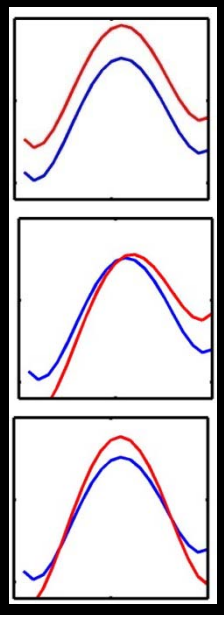
B's ≈ Ctrls	W's > Ctrls	
n.s.	$p < 0.05$	β_0
n.s.	n.s.	β_1
n.s.	$p < 0.0001$	β_2

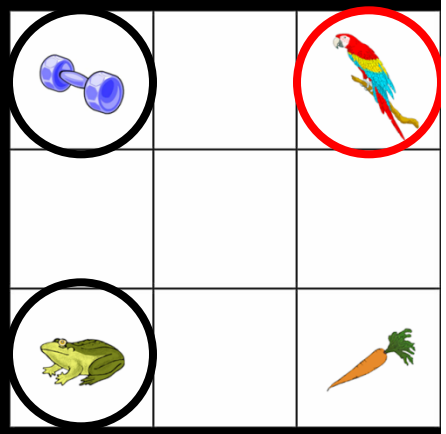


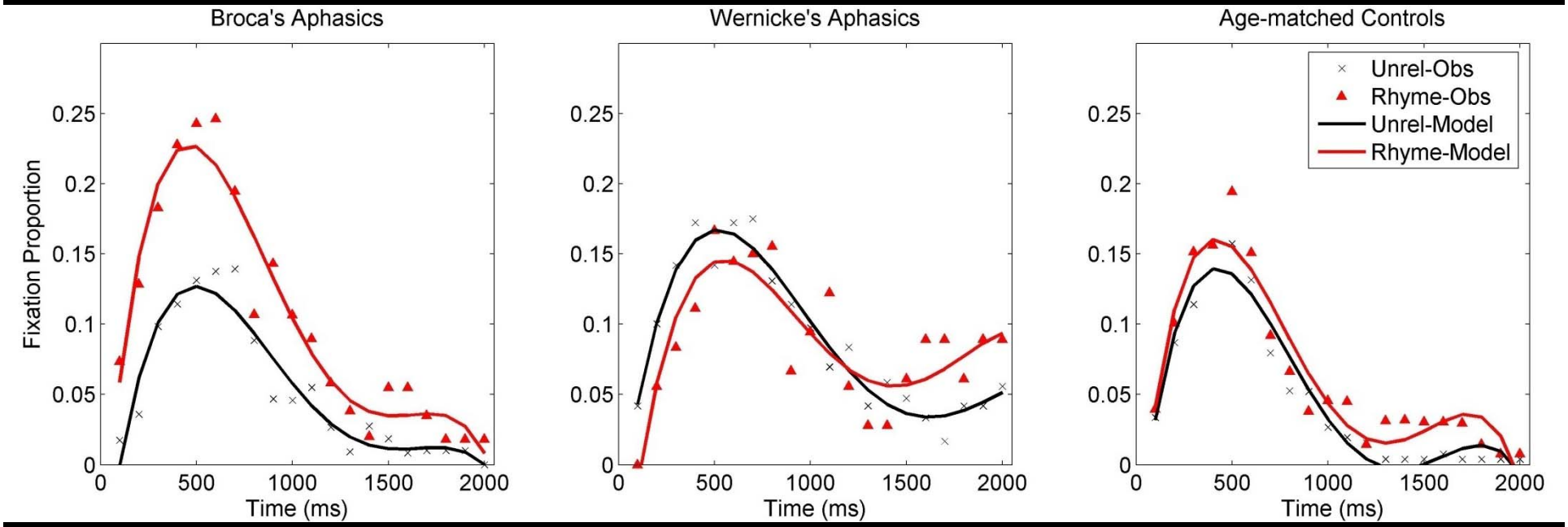




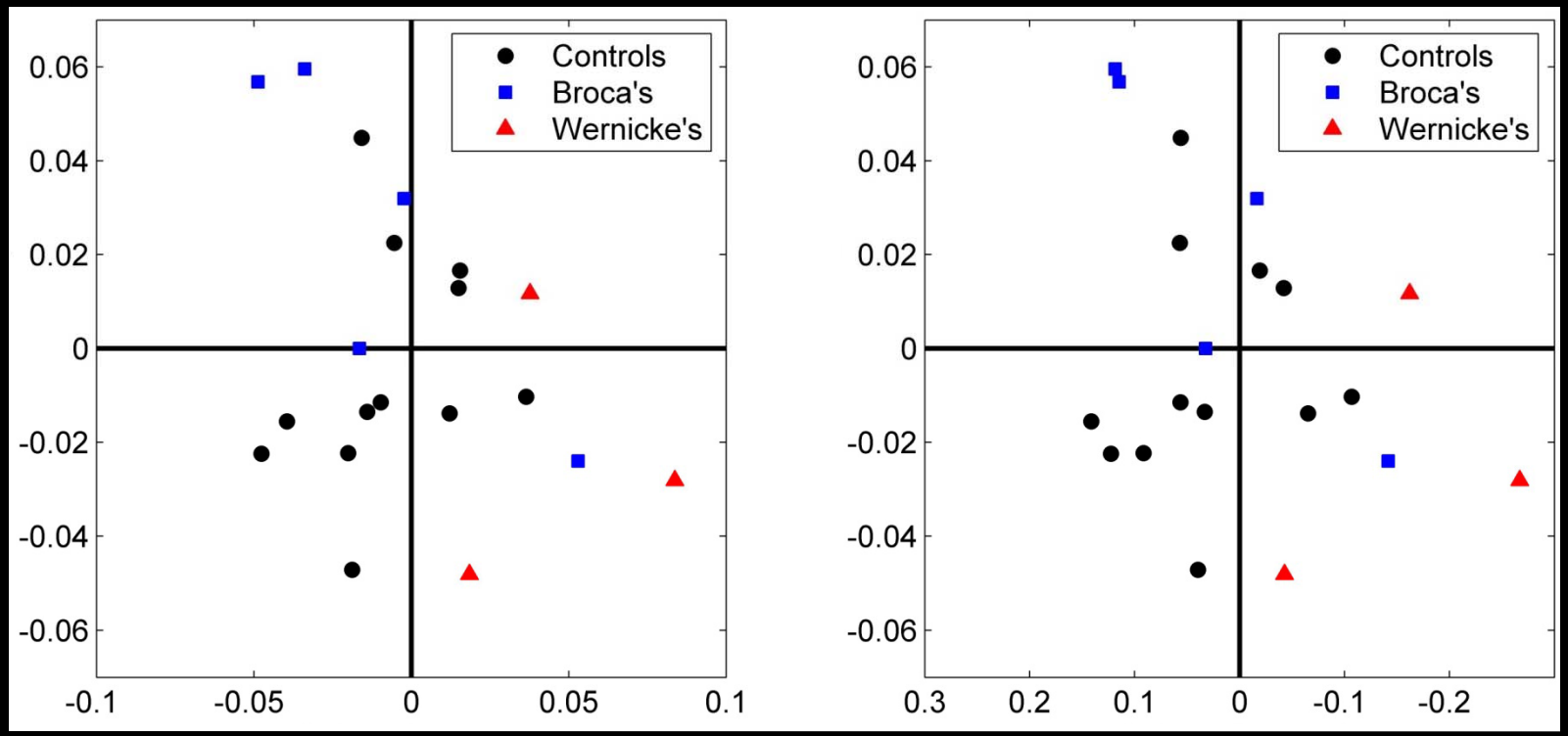
B's > Ctrls	W's ≈ Ctrls	
$p < 0.05$	n.s.	β_0
$p < 0.1$	n.s.	β_1
n.s.	n.s.	β_2







Effect Size Distribution

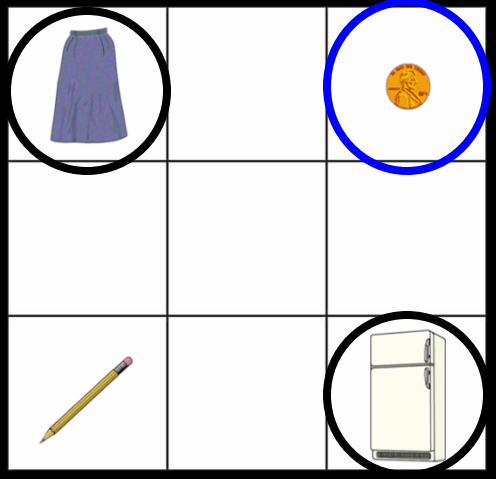


Correlation between rhyme and cohort effect sizes

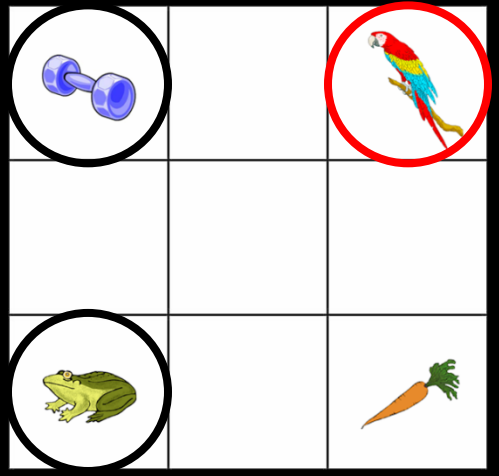
Overall (N=20): $r = -0.32$, $p > 0.15$ $r = 0.30$, $p > 0.2$

Patients (N=8): $r = -0.76$, $p < 0.05$ $r = 0.70$, $p = 0.053$

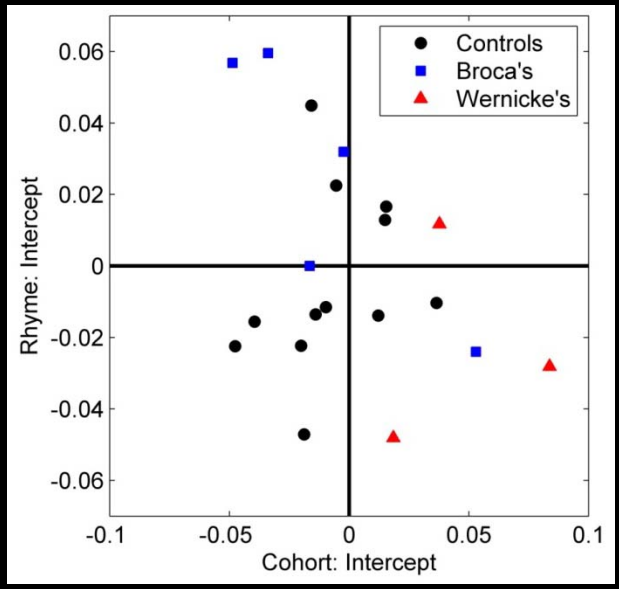
What did this study of spoken word recognition in aphasia tell us?



Wernicke's aphasics exhibit larger cohort effect



Broca's aphasics exhibit larger rhyme effect

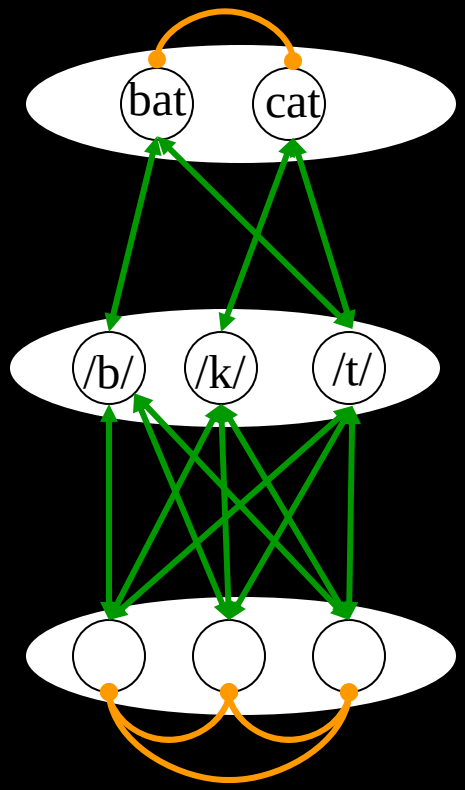


Negative correlation between effect sizes for patients

Intuition: this is not consistent with existing accounts

An account based on a single factor may be possible

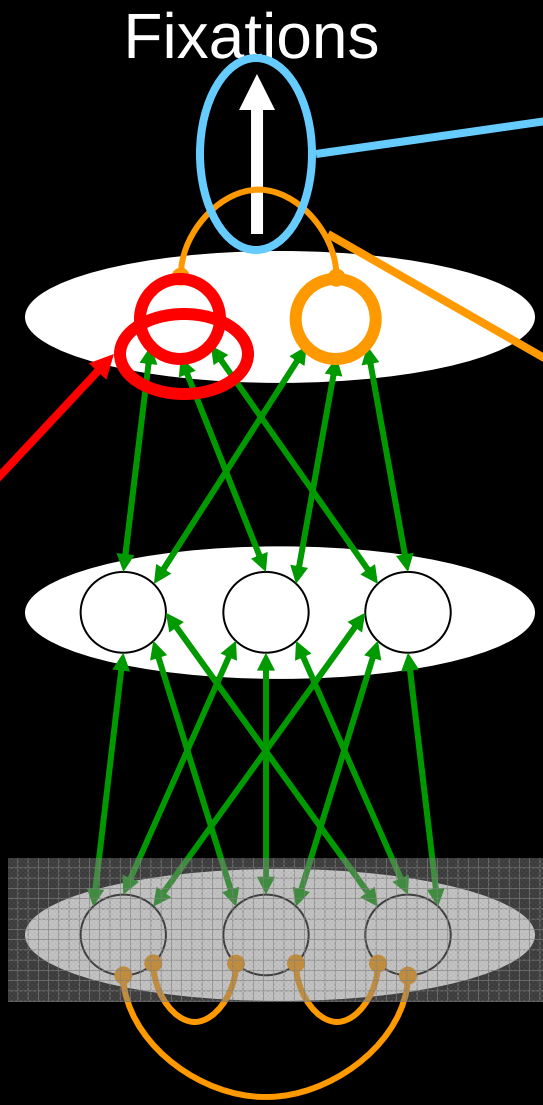
The TRACE Model of Speech Perception



(McClelland & Elman, 1986)

- Units interact through bi-directional weighted connections
- Consistent units at different levels have positive/excitatory weights (/b/→"bat"→/b/)
- Mutually-exclusive units in each layer have negative/inhibitory weights (/b/→/k/, "bat"→"cat")
- Unit activation is a nonlinear function of net input: $a_i = f(\Sigma_j a_j * W_{j \rightarrow i})$
- Unit activation decays over time

Towards a Computational Model of Aphasic Spoken Language Processing



Cognitive control
5. Response selectivity

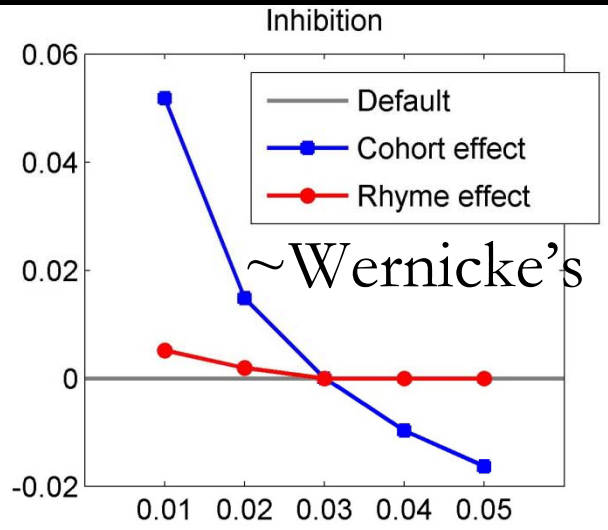
Rate of deactivation
1. Lexical inhibition

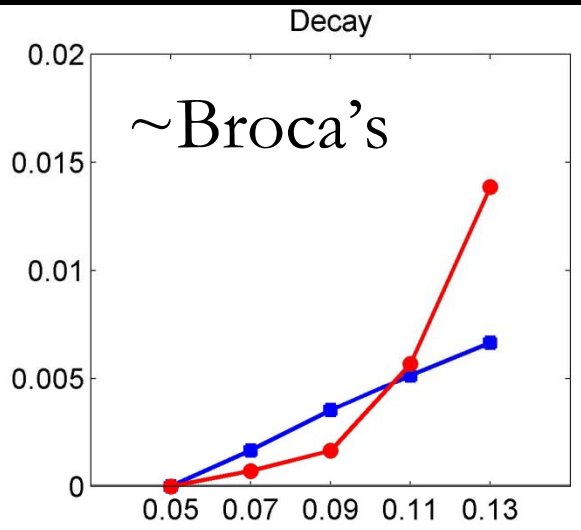
Working memory
2. Lexical decay rate

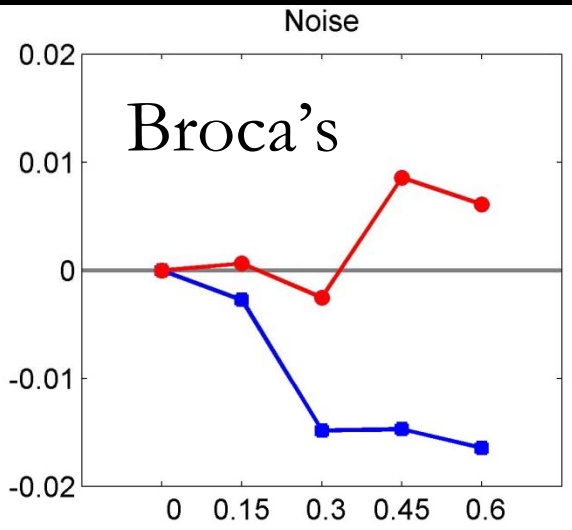
Rate/level of activation
3a. Responsiveness to input (input gain)
3b. Resting activation level

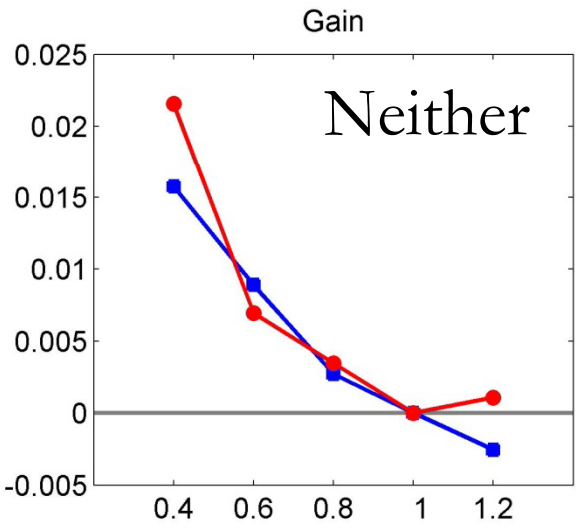
Perceptual impairment
4. Input noise

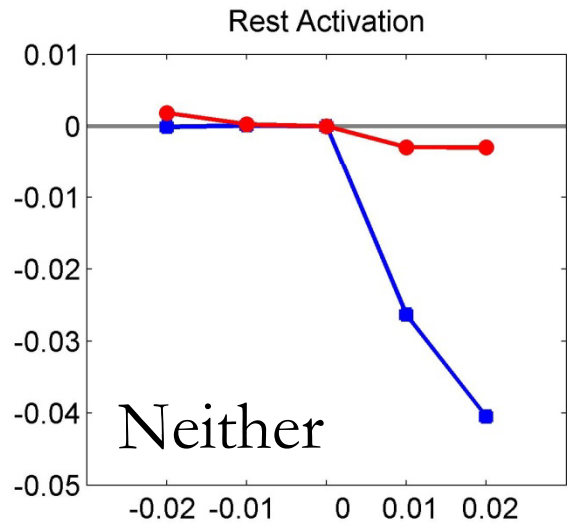
Simulation Results Summary

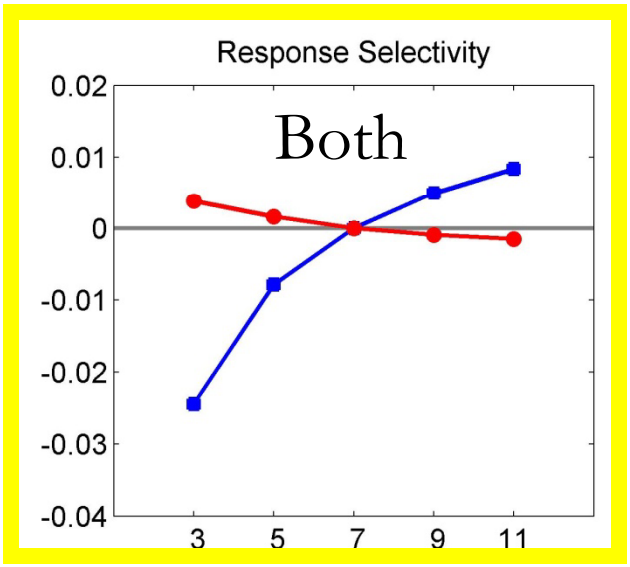












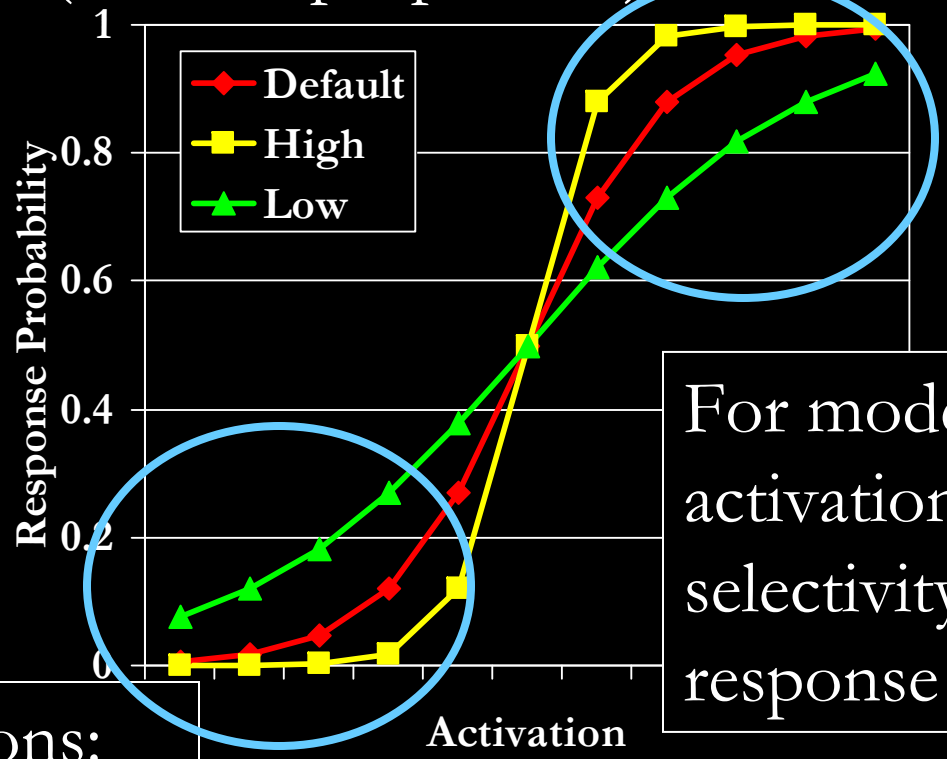
Simulation Results Summary

- Rate of deactivation (Lexical inhibition): ~Wernicke's
- Working Memory (Lexical decay): ~Broca's
- Rate/level of activation (Lexical gain; Lexical rest activation): Neither
- Perceptual impairment (Input noise): Broca's
- Cognitive control (Response selectivity): Both

➢ What is response selectivity?

Response Selectivity

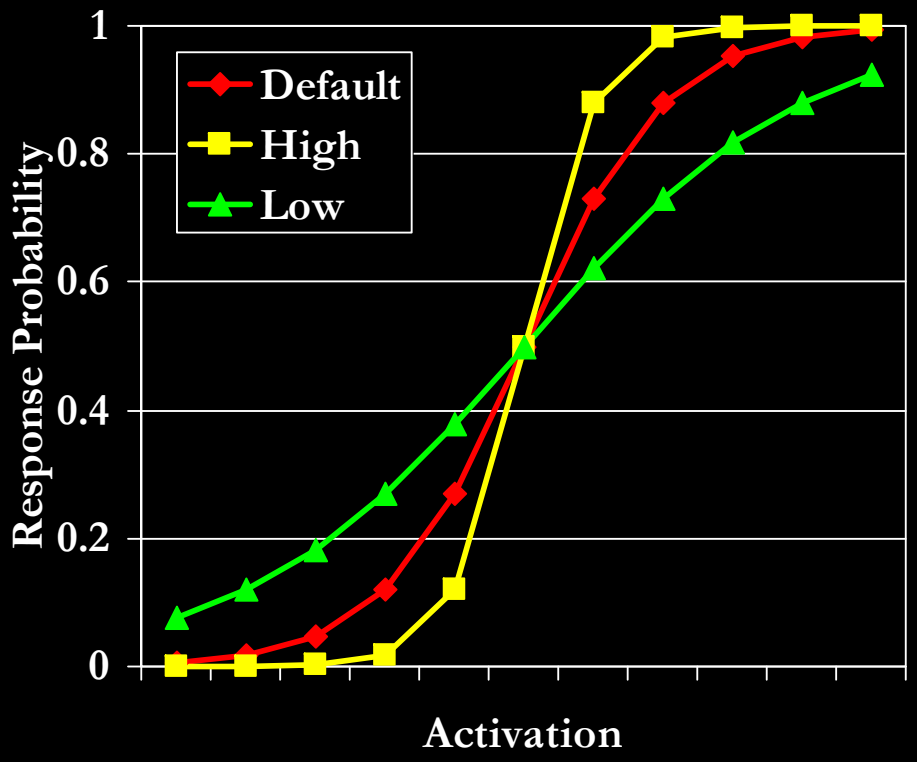
Slope of nonlinear relationship between lexical activation and response (fixation proportion)



For moderate-to-high activations: high selectivity → high response likelihood

For low activations: high selectivity → low response likelihood

Why it accounts for behavioral data



Low selectivity favors rhymes (low activation), disfavors cohorts (moderate activation) → Broca's aphasic pattern

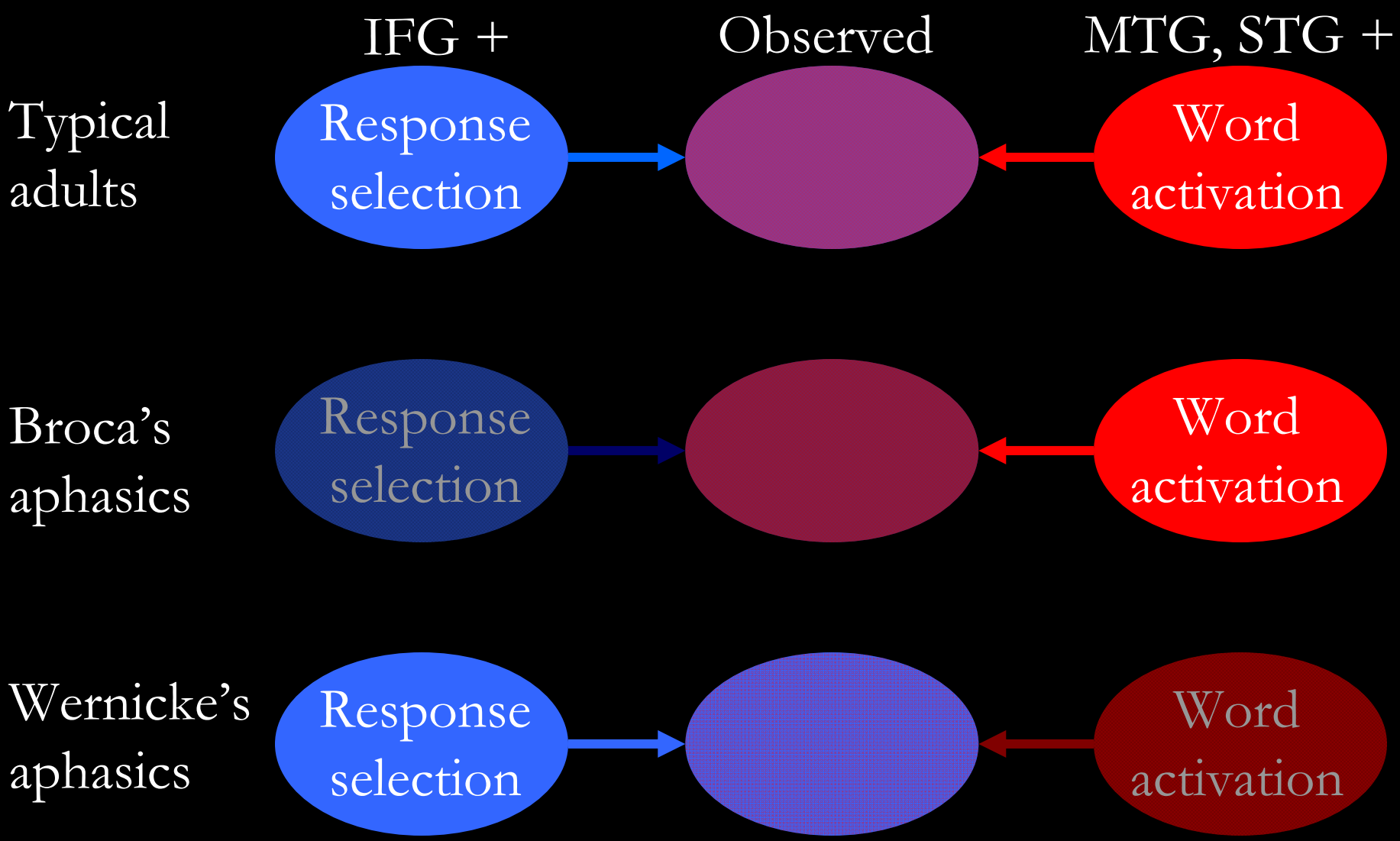
High selectivity favors cohorts (moderate activation), disfavors rhymes (low activation) → Wernicke's aphasic pattern

What does it mean?

- Cognitive control and IFG
  - Hypothesis: Response selectivity is a computational instantiation of "selecting among competing alternatives"
- Broca's aphasics tend to have damage to IFG
  - Impaired (reduced) response selectivity
- Wernicke's aphasics tend to have posterior damage
  - Hypothesis: Impaired (reduced) activity in posterior regions increases response selectivity

➢ Putting it together: The Dynamic Balance Hypothesis

The Dynamic Balance Hypothesis



Thank you

Collaborators: Jim Magnuson, J. Dixon, Eiling Yee, and Sheila Blumstein

Assistance: Ted Strauss

Funding: NIH grants F32HD052364 to DM, DC005765 to JSM, HD001994 to Haskins Labs, and DC00314 to Brown University.