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
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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?
Visual World Eye-Tracking Paradigm

(Alloppenna 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  
\( \beta_0 \)  
\( \beta_1 \)  
\( \beta_2 \)  
\( p < 0.05 \)  
\( p < 0.0001 \)
B’s >Ctrls
\[ p < 0.05 \]
\[ p < 0.1 \]
n.s.

W’s \approx\text{Ctrls}
n.s.

\beta_0
\beta_1
\beta_2

Unrel-Obs
Rhyme-Obs
Unrel-Model
Rhyme-Model

Broca’s Aphasics
Wernicke’s Aphasics
Age-matched Controls
Effect Size Distribution

Correlation between rhyme and cohort effect sizes

Overall (N=20): $r = -0.32, p > 0.15$  
Patiens (N=8): $r = -0.76, p < 0.05$
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

Intuition: this is not consistent with existing accounts

Negative correlation between effect sizes for patients

An account based on a single factor may be possible
The TRACE Model of Speech Perception

- 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: $a_i = f(\sum_j a_j W_{ji})$
- Unit activation decays over time

(McClelland & Elman, 1986)
Towards a Computational Model of Aphasic Spoken Language Processing

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

Rate of deactivation
1. Lexical inhibition
2. Lexical decay rate

Perceptual impairment
4. Input noise

Cognitive control
5. Response selectivity
Simulation Results Summary

- **Inhibition**
  - Default
  - Cohort effect
  - Rhyme effect

- **Decay**
  - ~Broca’s

- **Noise**
  - Broca’s

- **Gain**
  - Neither

- **Rest Activation**
  - Neither

- **Response Selectivity**
  - Both
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 $\Rightarrow$ high response likelihood

For low activations: high selectivity $\Rightarrow$ low response likelihood

Activation Response Probability

Default High Low

0 0.2 0.4 0.6 0.8 1
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

Typical adults
IFG +
Response selection
Observed
MTG, STG +
Word activation

Broca’s aphasics
Response selection
Word activation

Wernicke’s aphasics
Response selection
Word activation
Thank you

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