

# Broca's Area in Syntactic Processing

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# Background

- Linguistic Theory: different modules of linguistic competence
  - **Example:** the syntactic component, governing hierarchical organization of words and phrases, vs. the phonological component, dealing with sound structure
  - **Project:** Identification of cortical areas responsible for our knowledge of these distinct aspects of linguistic competence
  - **Specifically:** The role of Broca's area (BA 44,45) in syntactic processing

# Background: ERP Studies

- P600 (Osterhout & Holcomb 1992). Index of syntactic ill-formedness? Or perhaps not language-specific (Patel et al. 1998)
- Left Anterior Negativity (LAN): associated with error detection in grammatical processing (Münter et al. 1993, Friederici et al. 1993)
- Detection by left-anterior electrodes suggests the involvement of Broca's Area

# Background: Aphasia

- Initially (following Broca's insight): Broca's Area as underlying speech production
- Subsequently: Broca's area as a locus of syntactic processing (Geschwind 1965, Goodglass 1976)
- More recently: Conflicting views; contrary claims (Dronkers & Ludy 1998, Caplan et al. 1996), and claims supporting Broca's Area as underlying syntax (Grodzinsky & Finkel 1998)

# Background: Neuroimaging

(Some prevailing views; no time for a literature survey here)

- In general: claims concerning the activation of Broca's area in a number of syntactic and non-syntactic tasks
- An increase in Broca's activation with increased syntactic complexity (Stromswold et al. 1996; Just & Carpenter 1996). Difficult to distinguish functional specialization from general complexity.
- "Syntax vs. Semantics" studies (e.g. Dapretto & Bookheimer 1999, Kang et al. 1999). Broca's area more active for 'syntax' vs. 'semantics', although the contrasting conditions in the studies might involve each.

# The Present Study

- **Goal:** Identify brain-areas associated with syntactic processing.
  - Error-detection paradigm from ERP studies of syntactic anomaly (“phrase-structure”; Neville et al. 1991)
  - Linguistic control condition involving (1) normal syntactic processing, and (2) error detection of misspelled words
  - Linguistic control comparable in difficulty (as measured behaviorally) to syntactic error detection

# Stimuli

- Sentential stimuli: grammatical (GR) and spelling (SP)
- Identical lexical material in each type, and differ only in type of error
  - GR: One or two word-order errors
  - SP: One or two spelling errors

# Grammatical Stimuli

One Error

The teacher talked about  
the proof the of theorem.

Two Errors

Teacher the talked about  
the proof the of theorem.

# Spelling Stimuli

One Error

**Tfe teacher talked about  
the proof of the theorem.**

Two Errors

**Tfe teacher talked about  
the proof of the theuorem.**

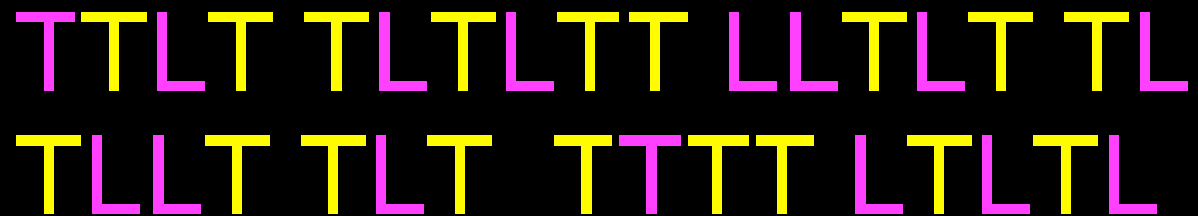
# Comments

- Subjects were instructed to read each sentence slowly and carefully, and respond 1 or 2 (button press)
- One- vs. two-error design allows stimuli to be blocked, while maintaining a task that requires the processing of each individual sentence

# Control Condition/CO

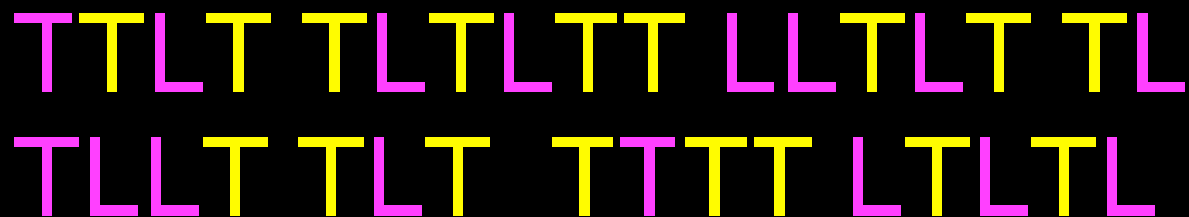
One or two matches to the letter/color combination found in the upper left?

One Match



TTLT TLTLTT LLTLT TL  
TLLT TLT TTTT LTLTL

Two Matches



TTLT TLTLTT LLTLT TL  
TLLT TLT TTTT LTLTL

# Notes on the Conditions

- GR and SP each combine linguistic processing with error-detection; the type the error differs:
  - GR: syntactic violation
  - SP: problem with orthographic representation
  - CO: controls for serial search and short-term memory of targets

# Stimuli

1. Each presented for 5500ms
2. Accuracy and RT recorded on line
3. Blocks CO-SP-CO-GR-CO...
4. Each block contained 3 one-error, and 3 two-error stimuli in a random sequence
5. Each run consisted of 5 CO blocks, 2 SP blocks, and 2 GR blocks

# Subjects and Imaging

**Subjects:**  $n = 8$ ; 6 male and 2 female. Right-handed native speakers of English.

**Scanner:** Conventional 1.5T system (Hitachi)

- SARGE sequence
- TR/TE = 70/40ms; flip angle =  $30^\circ$ ; FOV = 256mm; slice thickness = 8mm
- Regions covered:  $z = 0 \approx +32\text{mm}$  above AC/PC

# Behavioral Data

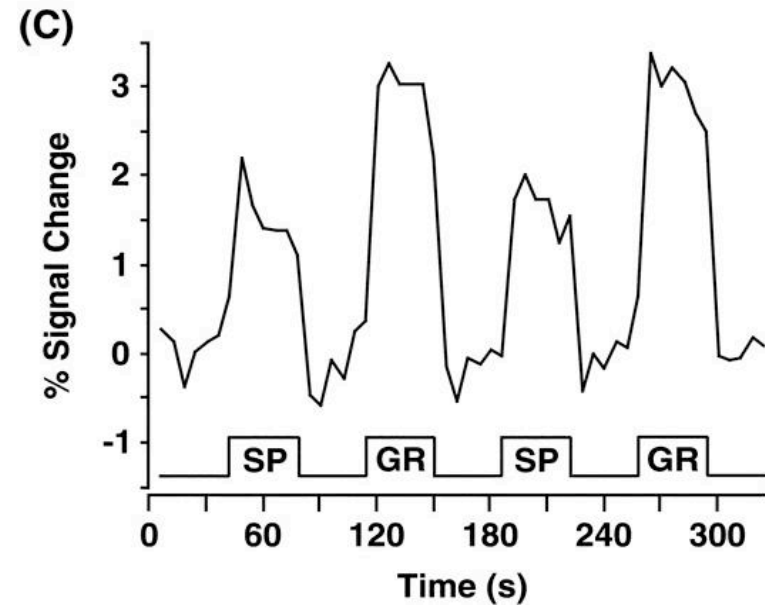
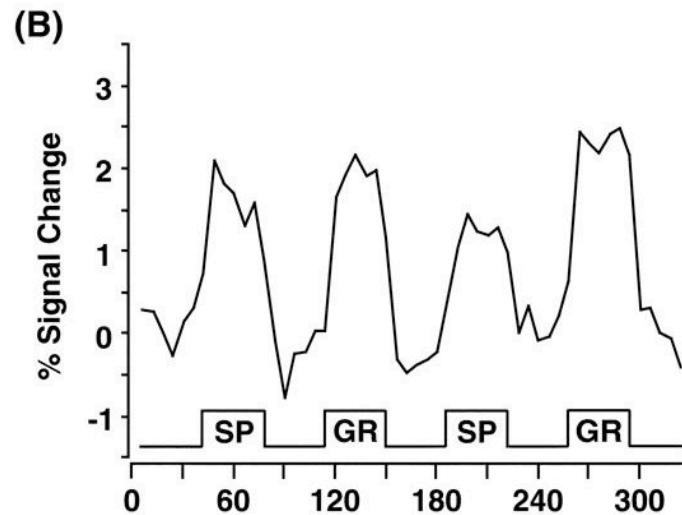
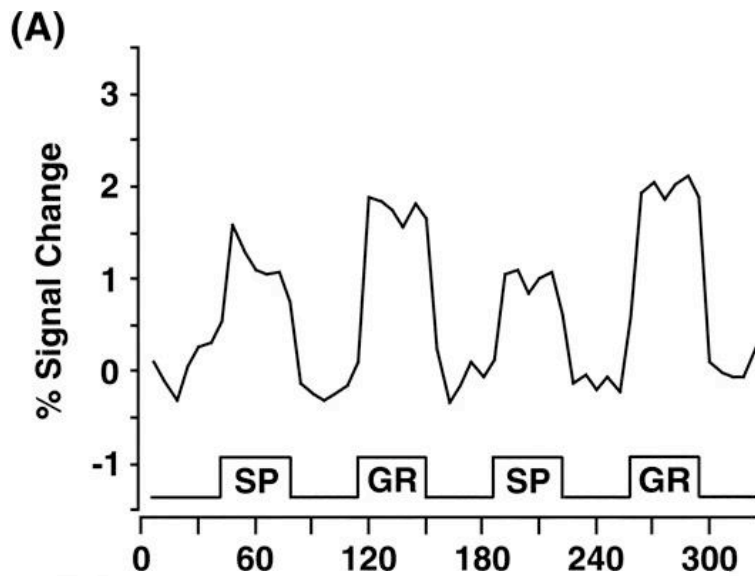
<u>Condition</u>	<u>RT(ms)</u>	<u>Accuracy(%)</u>
Spelling 1	4266±454	96.1±2.1
Grammar 1	4293±384	92.2±4.5
Spelling 2	3610±446	89.6±5.1
Grammar 2	4109±400	84.4±7.5

**Statistically:** Some differences between SP and GR.  
Overall, no consistent significant difference in both RT and accuracy across conditions.

# Analysis Procedure

- Three regions of interest:
  - AG/SMG (Angular Gyrus and Supramarginal Gyrus; 39/40)
  - Wernicke's Area (22)
  - Broca's Area (44/45)
- Regions consisting of four contiguous voxels with the highest  $t$ -values above a 2.57 threshold, in comparison with the CO condition

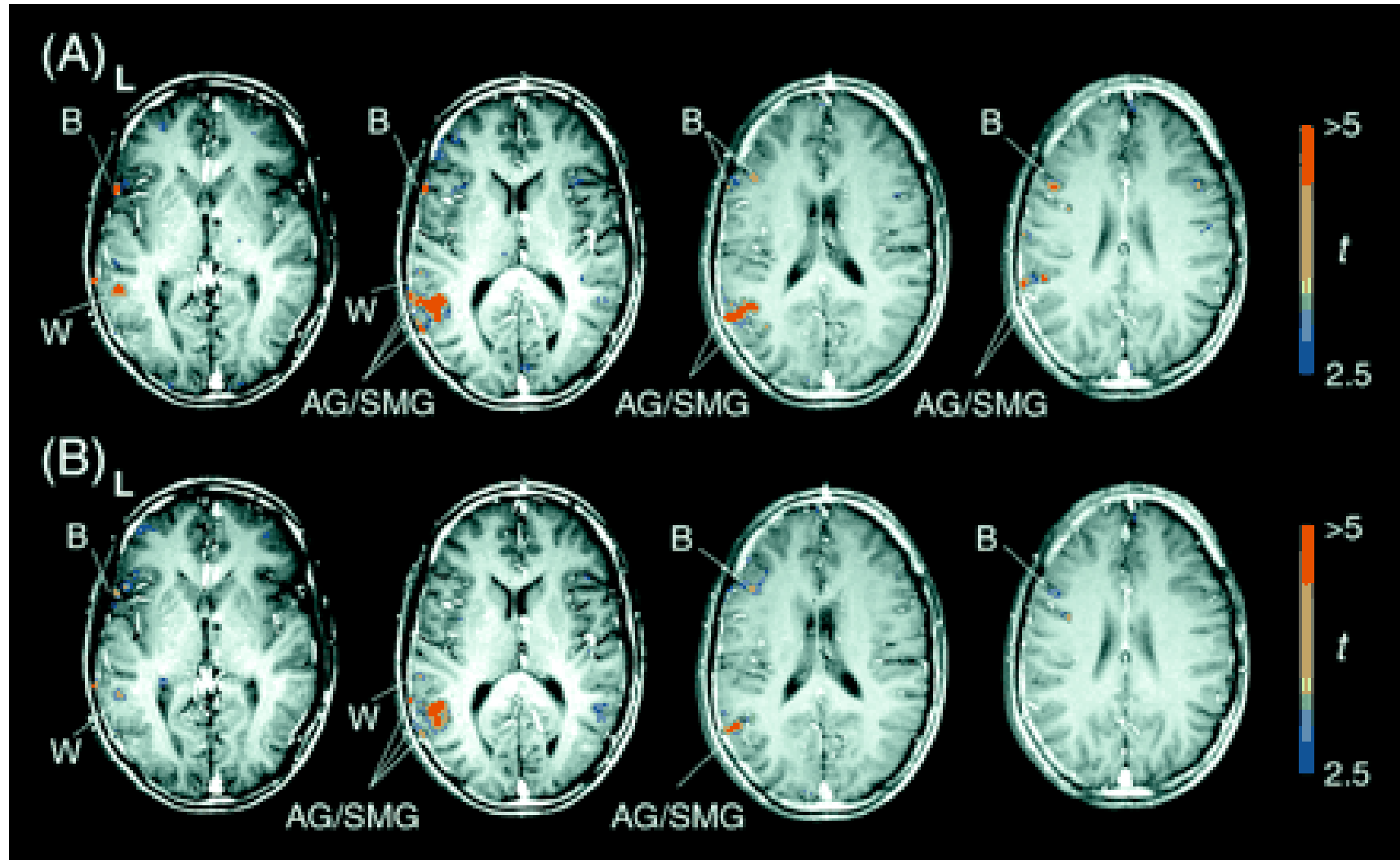
# Activation by Region



## KEY

- (A): AG/SMG
- (B): Wernicke
- (C): Broca

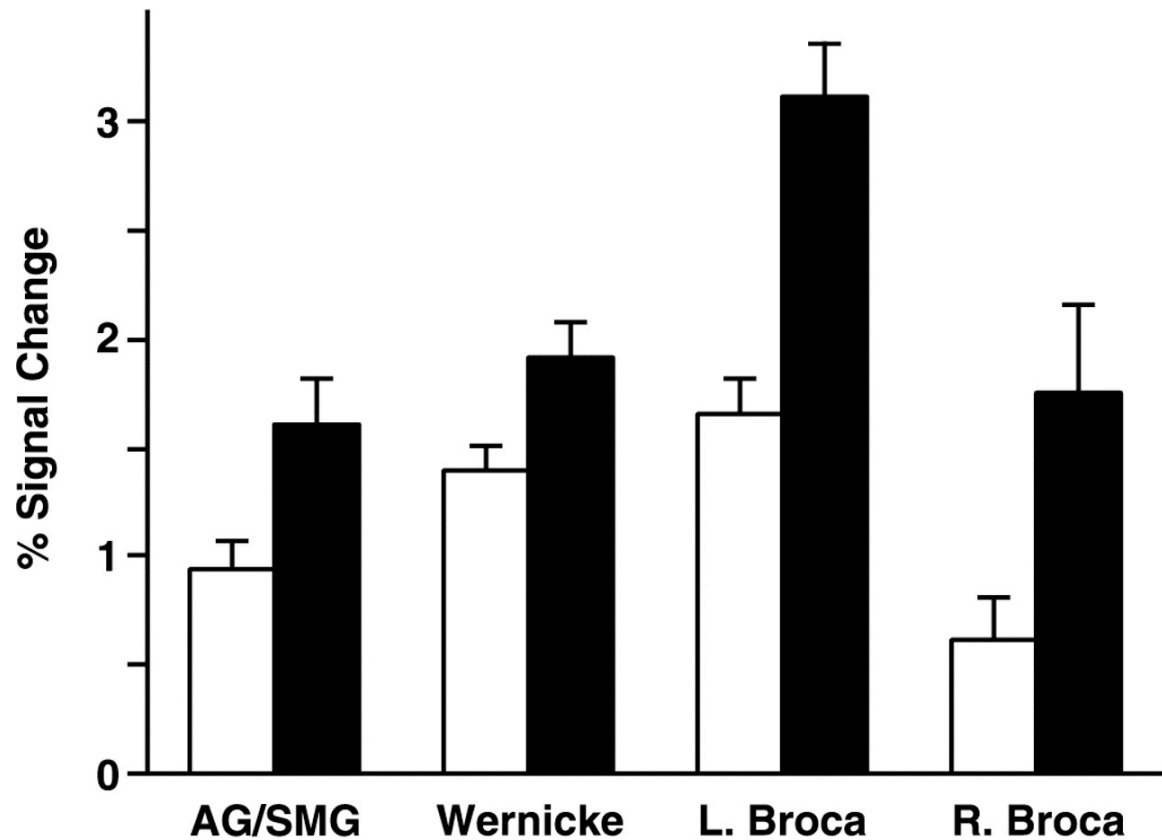
# Images (GR/CO, SP/CO)



# Histogram

Histogram with %-signal change by area, for each of SP and GR.

In general, greater activation for GR than for SP



White: SP; Black: GR

# Statistics

<u>Region</u>	<u>GR vs. SP</u>	
AG/SMG	7.1*	
Wernicke	6.9*	*, P < .05
L. Broca	22.9**	
R. Broca	5.7*	** ,P < .0001

(*F*-values of main effect of tasks in an ANOVA (condition X block) in each region)

**In sum:** Difference between GR/SP in L. Broca was significantly greater than the GR/SP difference in the other cortical areas.

# Interpretation

- General complexity cannot be the only difference between GR and SP, as the behavioral data show
- The difference between GR and SP are attributable to the different linguistic systems involved in each task
- Broca's area is significantly more activated by GR than SP in comparison with other areas

# Questions

- Source for the GR/SP contrast in AG/SMG and Wernicke's; feedback, or syntactic processing in these components as well?
- Direct relationship between these results and e.g. the LAN from the ERP literature

# Conclusions

- Experiment employs two sets of sentential stimuli, which differ in terms of orthographic representation vs. increased syntactic processing
- Different types are matched in terms of general complexity
- The difference between GR and SP is most pronounced in Broca's area, indicating this regions specialization for syntactic processing (though not necessarily exclusively this)