

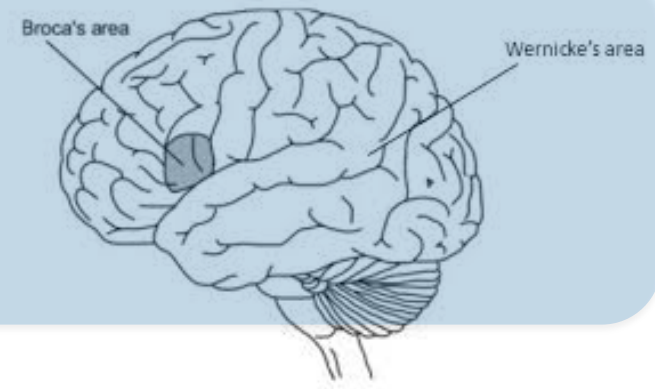
# Main bodies of research in the cognitive neuroscience of combinatorial syntax & semantics

## ■ Violation studies

- Comprehension of expressions that violate your knowledge of how words should combine together
- Primarily EEG



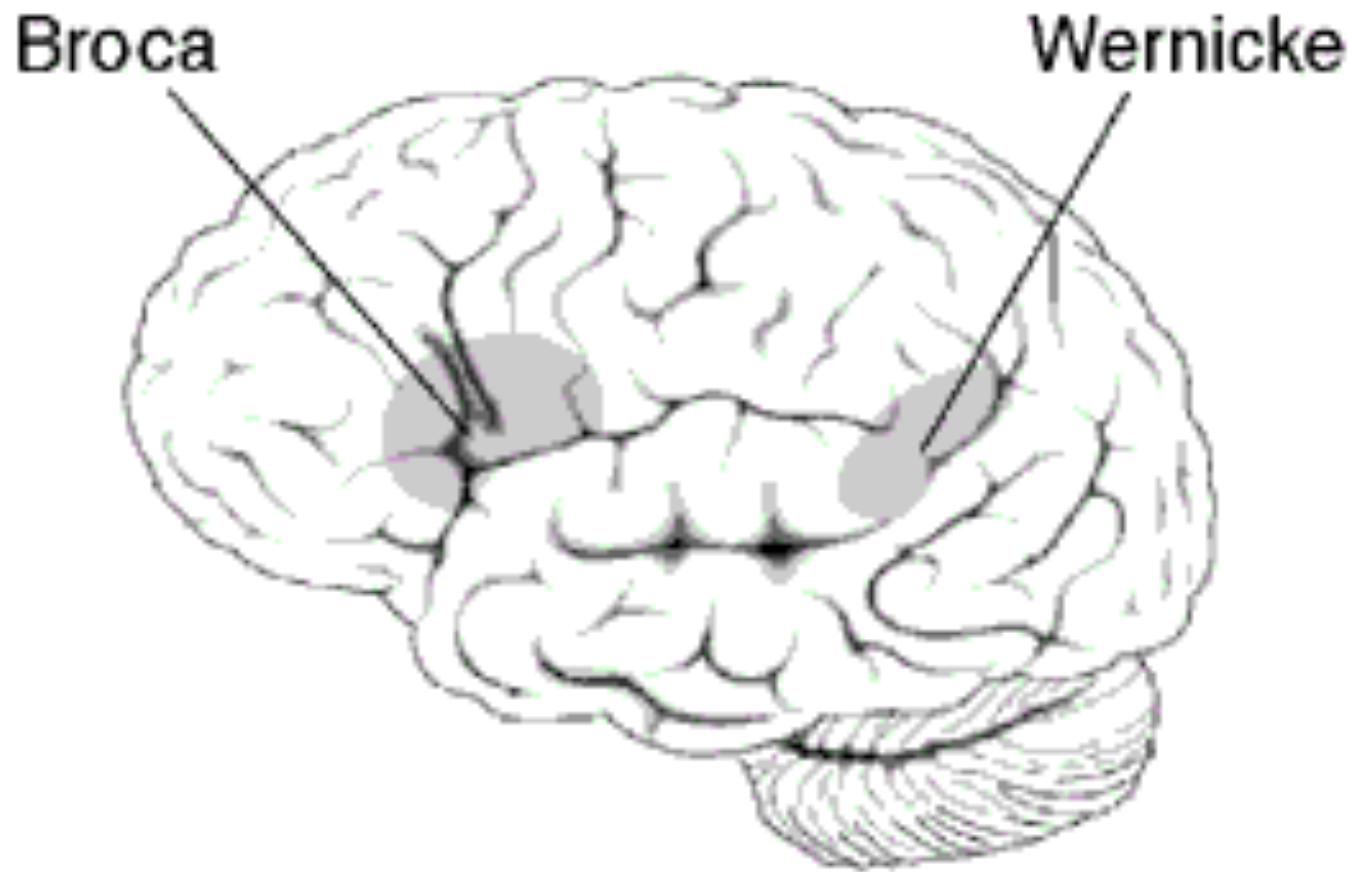
- Hemodynamic research on Broca's area
  - Long debate about whether and how Broca's area contributes to syntactic processing



- Basic composition

- What neural activity reflects the basic operation of composing elements together into larger expressions?

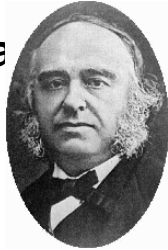
**black** **cat**



How did Broca enter the neuroscience of syntax?

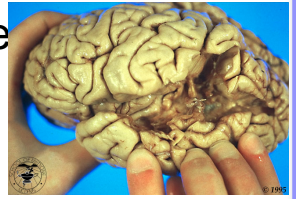
## 1. Paul Broca & Broca's aphasia

- First localization of language function (**1861**).
- Patient could only produce a single syllable "tan".
- Severe production problem.
  - Broca's aphasia
- Lesion in the posterior part of the left inferior frontal gyrus
  - Broca's area

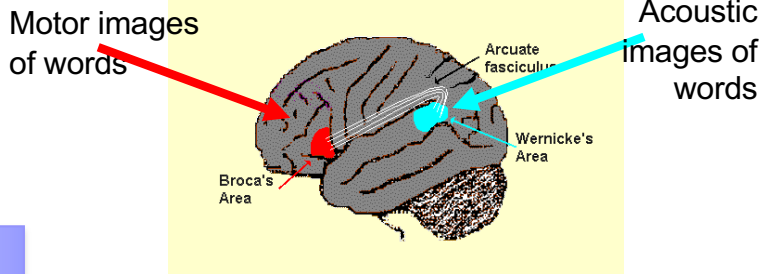


## 2. Carl Wernicke and Wernicke's aphasia

- A language problem distinct from Broca's aphasia first described by Carl Wernicke (**1874**).
- Damage to the boundary of the temporal and parietal lobes --> Wernicke's area.
- Fluent but disordered speech. Similar writing.
- Impaired understanding of speech. Impaired reading.



## 3. The classic model of language in the brain



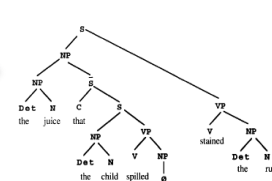
## 4. Broca's aphasia not just a production problem

- Caramazza & Zurif (**1976**): Broca's aphasics fail on sentences whose interpretation depends on the right syntax. For example, movement that reverses the canonical order of agent and patient elicits errors.
  - Easy: The girl chased the boy.
  - Hard: The boy was chased \_ by the girl ...

## 4. Stromswold et al. (1996): Localization of syntactic comprehension by positron emission tomography

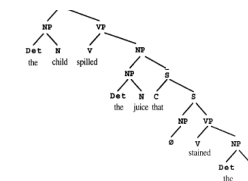
- Center-embedded structures activate Broca's are more than right-branching ones.

Center-embedded:

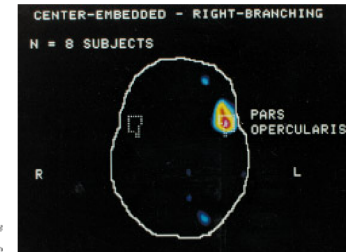


Center-embedded construction: The juice that the child spilled \_ stained the rug

Right branching



Right branching construction: The child spilled the juice that \_ stained the rug



# What google had to say about “syntax in the brain” today (Oct 26 2020)

syntax in the brain



All

Images

Videos

News

Shopping

More

Settings

Tools

About 51,300,000 results (0.45 seconds)

The IFG is a region of the **brain** which is found to be the most important aspect within a **syntactic** processing neural net. The IFG is responsible for parsing. It has been postulated that when it comes to **syntactic** knowledge, the left anterior **brain** appears to be involved in this type of processing. Jan 25, 2019



en.wikiversity.org › wiki › Syntax\_in\_the\_Brain

[Psycholinguistics/Syntax in the Brain - Wikiversity](#)

About Featured Snippets

Feedback

➤ What does the evidence look like?

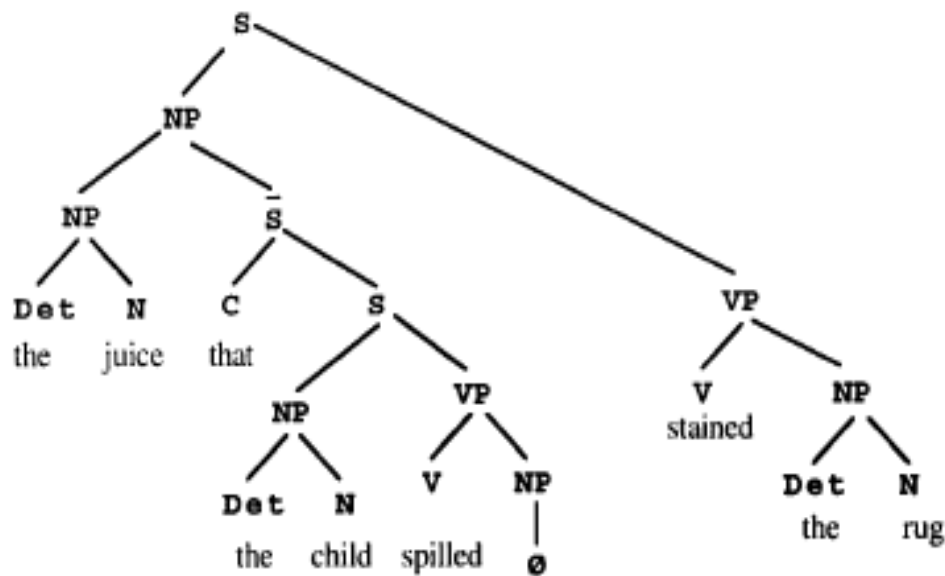
# Stromswold et al. (1996): Broca's area lights up for complex syntax

- A PET study contrasting center-embedded and right-branching structures.
  - Center-embedded:  
*The juice that the child spilled \_\_\_ stained the rug.*
  - Right branching:  
*The child spilled the juice that \_\_\_ stained the rug.*
- Lots of psycholinguistic evidence that center-embedded structures are much harder to comprehend than right-branching structures.

# Complex vs. simple sentences

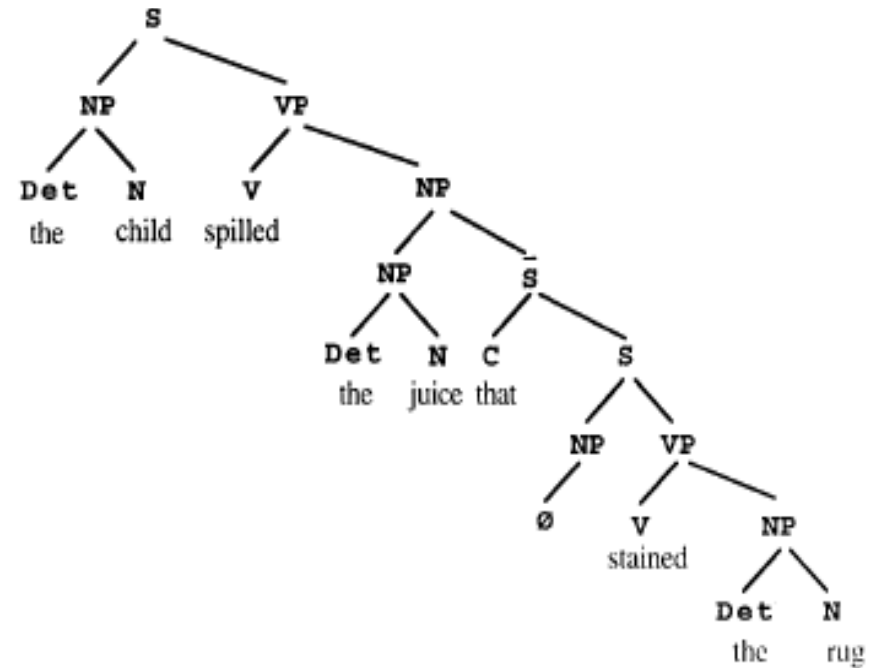
Stromswold et al., 1996:

Center-embedded:



Center-embedded construction: The juice that the child spilled \_\_\_ stained the rug

Right branching



Right branching construction: The child spilled the juice that \_\_\_ stained the rug

- Blocked design.

# ***Complex vs. simple sentences***

Stromswold et al., 1996: Broca's area

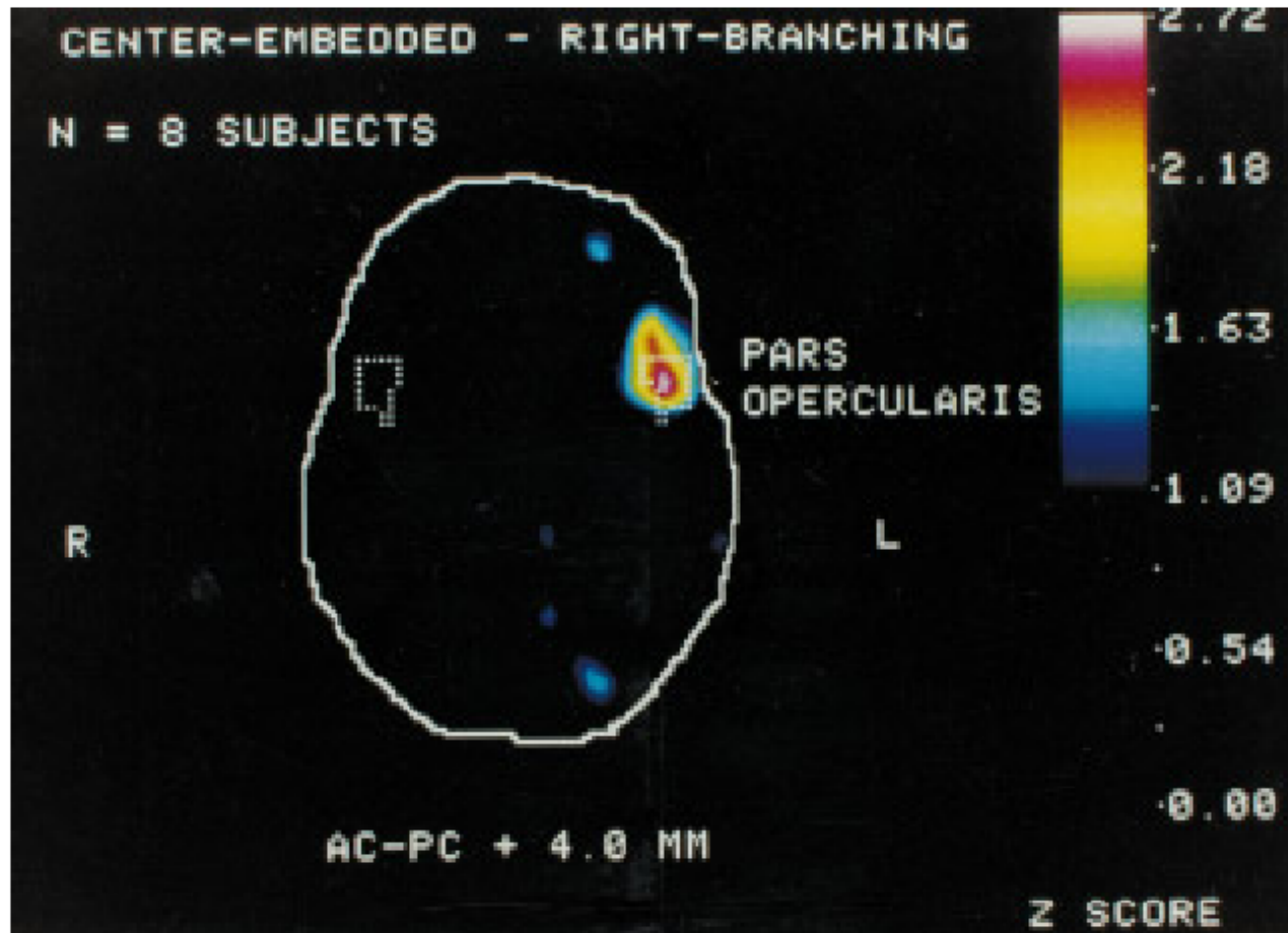


FIG. 2. Statistical parameter map (omnibus subtraction image) showing increased rCBF in the pars opercularis of the left hemisphere during judgments of semantic plausibility of sentences with center-embedded compared to right-branching relative clauses (condition 1 – condition 2).



# PET Studies of Syntactic Processing with Auditory Sentence Presentation

David Caplan,\* Nathaniel Alpert,† and Gloria Waters\*‡

\*Neuropsychology Laboratory, Department of Neurology, and †Division of Nuclear Medicine, Department of Radiology, Massachusetts General Hospital, Fruit Street, Boston, Massachusetts 02114; and ‡Department of Communication Disorders, Boston University

OBJECT CLEFT:

*It was **the juice** that the child enjoyed \_*

VS.

SUBJECT CLEFT:

*It was **the child** that\_ enjoyed the juice.*

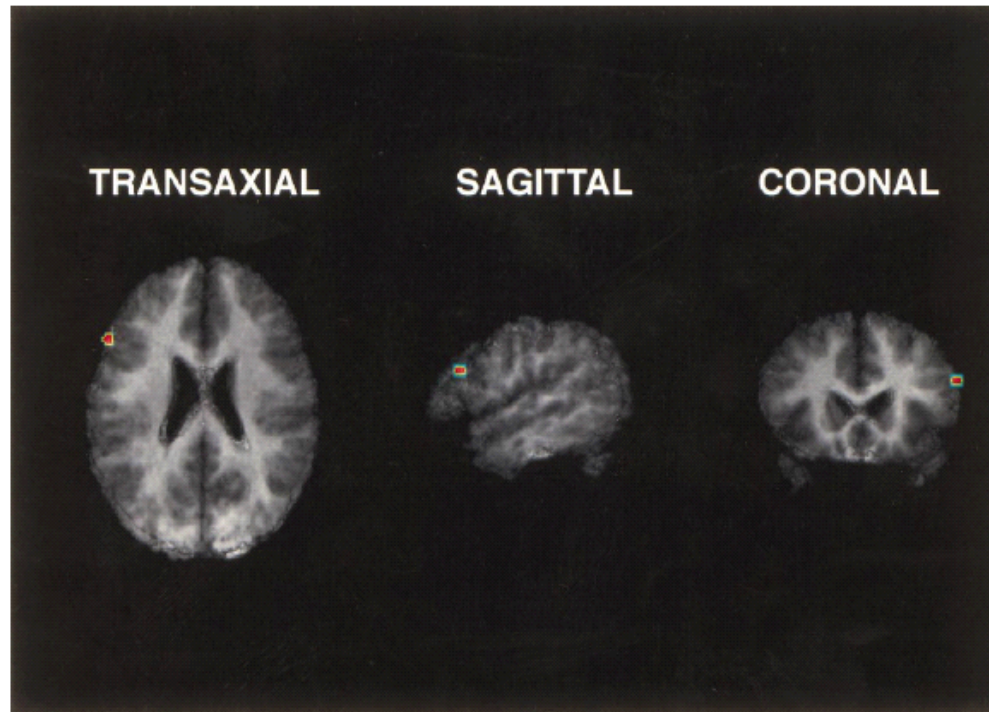


FIG. 1. SPM image of the brain showing increased blood flow in Broca's area when subjects processed auditorily presented cleft object compared to cleft subject sentences.



## **Broca's activation due to syntax or...**

- Increased working memory demands?
- How can we test this?

# **Broca's area, sentence comprehension, and working memory: an fMRI study**

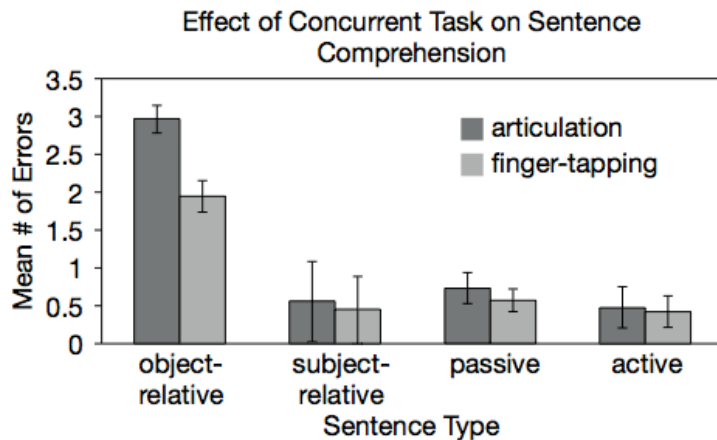
Corianne Rogalsky, William Matchin and Gregory Hickok\*

## **Towards mechanism:**

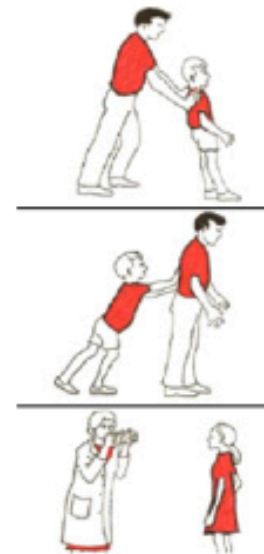
### **Verbal working memory and articulatory rehearsal**

- The decay of phonological information can be prevented by continuously articulating it subvocally (Baddeley's "phonological loop").
- Hypothesis:
  - Articulatory rehearsal aids the comprehension of syntactically complex sentences.
  - Broca's area (as a production area) houses the articulatory rehearsal mechanism.

# Rogalsky, Matchin & Hickok (2008): Does a secondary task of articulatory rehearsal eliminate a complexity effect in Broca's area?

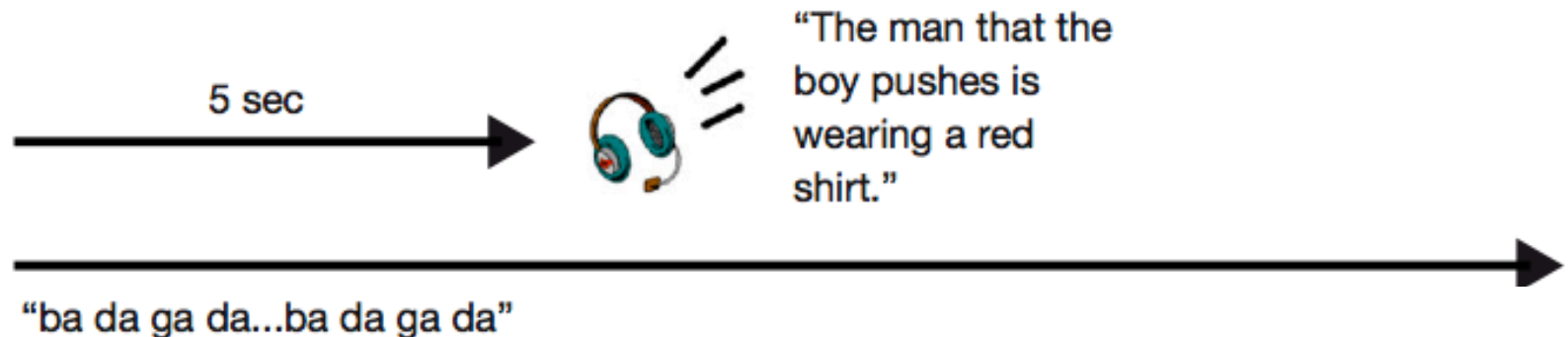


**BEHAVIOR**



Subject points to matching picture

Behavioral data: only object relatives significantly worsened by articulatory rehearsal



# Rogalsky, Matchin & Hickok (2008): Does a secondary task of articulatory rehearsal eliminate a complexity effect in Broca's area?

- fMRI study: participants judge subject and object relatives for plausibility. **BRAIN**
  - Object Relative: The money that the robber stole was in the bank vault.
  - Subject Relative: The robber that stole the money was in the bank vault.
  - Object Relative: #The robber that the money stole was in the bank vault.
  - Subject Relative: #The money that stole the robber was in the bank vault.

# Rogalsky, Matchin & Hickok (2008): Does a secondary task of articulatory rehearsal eliminate a complexity effect in Broca's area?

**BRAIN**

Original Stromswold result:

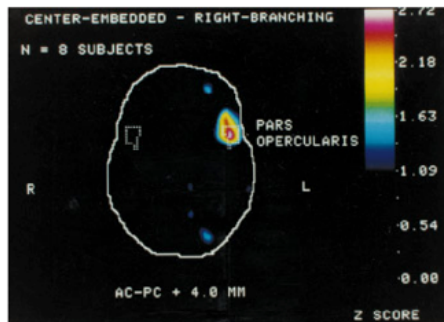
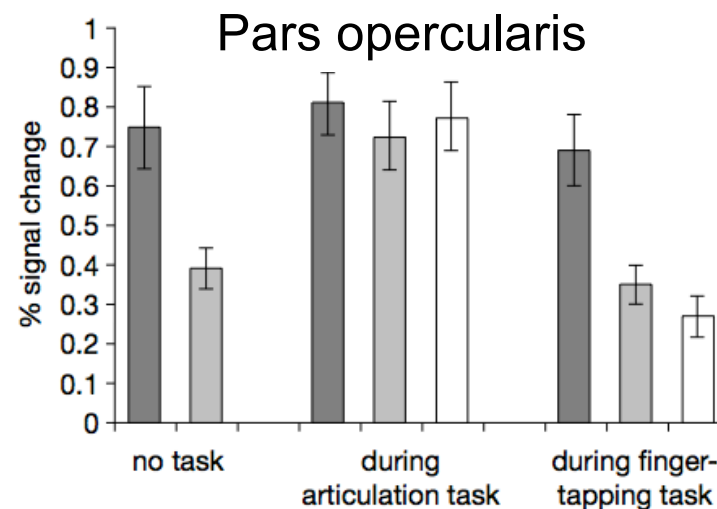


FIG. 2. Statistical parameter map (omnibus subtraction image) showing increased rCBF in the pars opercularis of the left hemisphere during judgments of semantic plausibility of sentences with center-embedded compared to right-branching relative clauses (condition 1 - condition 2).



■ object-relative      ■ subject-relative      □ task only

- Articulatory rehearsal elevates the activation level of the subject relatives, such as that no OR vs. SR effect is observed. Under this secondary task, Broca's activity is saturated.
- Evidence for articulatory rehearsal as a **possible** source of the syntactic "complexity" effect in Broca's region.
- Does not show though that the LIFG increase for ORs during "no task" is caused by articulatory rehearsal.

# Broca.. Production.. Syntax..

- Still no consensus on the role of the LIFG in language/sentence processing.
- However, if comprehension involves some production mechanisms, then some engagement of Broca's area could be expected in comprehension even if the region is fundamentally a production region.
- Further reading:

FEATURE ARTICLE

## The Cortical Organization of Syntax

William Matchin<sup>1</sup> and Gregory Hickok<sup>2,3</sup>

<sup>1</sup>Department of Communication Sciences and Disorders, University of South Carolina, Columbia, SC, 29208, USA, <sup>2</sup>Department of Cognitive Sciences, University of California, Irvine, Irvine, CA, 92697, USA <sup>3</sup>Department of Language Science, University of California, Irvine, Irvine, CA, 92697, USA

Address correspondence to William Matchin. Discovery 1 Room 202D, 915 Greene St., Columbia SC 29208. Email: matchin@mailbox.sc.edu