



What is neurolinguistics?

- Study of the neural bases of language
- But what is language?
 - **One of our most complicated cognitive skills we have**
 - **So we better have some hypotheses in mind about *what language is like* before we start asking the question *how is language instantiated in the brain.***



Aspects of language

- Static representations, i.e., linguistic knowledge.
 - **Studied in THEORETICAL LINGUISTICS.**
- Real-time processing of language.
 - **Studied in PSYCHOLINGUISTICS.**
- Neural bases of language.
 - **Studied in NEUROLINGUISTICS.**

The healthy way to do neurolinguistics

1. Use prior knowledge of language to isolate neural correlates of linguistic processes

Linguistic theory

Psycholinguistics



2. Use neural correlates of linguistic processes as additional dependent variables in the study of language

The verb generation task

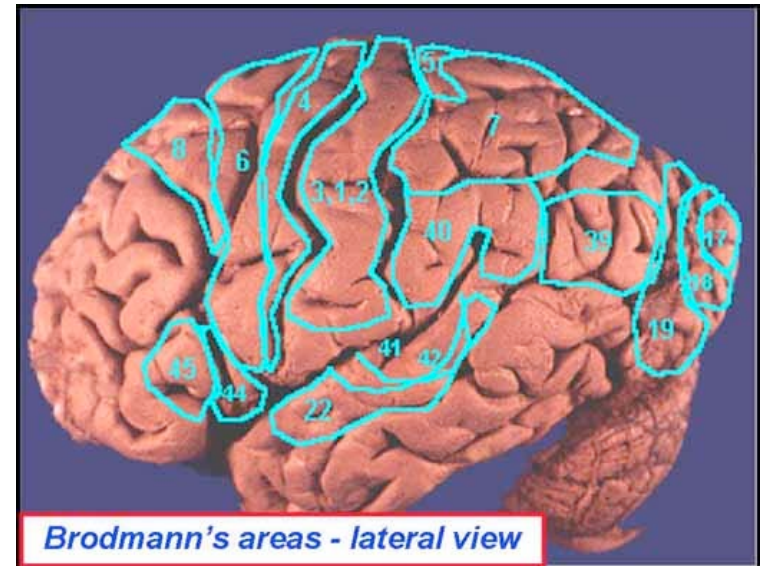
- In order to localize language, what brain regions are active during the verb generation task as opposed to when subjects are just staring at a cross?

SCISSORS

*Generate an associated verb
+
(overtly or covertly)*

The verb generation task

- In order to localize language, what brain regions are active during the verb generation task as opposed to when subjects are just staring at a cross?
- Xiong et al. (*Human Brain Mapping* 6:42–58 (1998)):
 - Left inferior frontal gyrus (BAs 45-47)
 - Broca's area (BAs 44/6)
 - Left superior temporal gyrus (BA 22)
 - Cingulate gyrus (BAs 32 and 24)
 - Inferior temporal gyrus (BA 37)
 - Occipital gyri (BAs 18 & 19)
 - Basal ganglia
 - Thalamus
 - Insula
 - Cerebellum





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What *kinds* of things do we know about the static representations of language?

- Speech sounds are grouped into categories, so-called *phonemes*.
- Within-category differences make no difference to meaning but across category differences do.
- E.g., [l] and [r] belong to different phonemes in English but not in Japanese.
 - **So ‘lip’ and ‘rip’ could never be two different words in Japanese. A Japanese speaker has trouble hearing and producing this difference.**



コインランドリー

COIN RAUNDRY

What *kinds* of things do we know about the **static representations** of language?

- Sentences are not word strings but have an internal structure.

The boys ate *burgers and fries.* ← *Constituent must stick together*

What did the boys eat _? Burgers and fries.

**What did the boys eat _ and fries? Burgers*

Burgers and fries the boys ate _.

**Burgers and the boys ate _ fries.*

**Burgers the boys ate _ and fries. (bad with a flat intonation)*



What *kinds* of things do we know about the **static representations** of language?

- Some sentences are structurally ambiguous.

In yesterday's show, we discussed sex with Dick Cavett.

- Ambiguity disappears in the passive:

In yesterday's show, sex was discussed with Dick Cavett.

- Explanation: possible to move *sex* without *with Dick Cavett* only when the two aren't a constituent.



What *kinds* of things do we know about the **static representations** of language?

- Syntax is different from just working out the meanings of words and putting them together somehow.

Me Tarzan, you Jane.

- Although we can all figure out what this sentence means, we also know that it does not obey the grammar of English.



What *kinds* of things do we know about the **static representations** of language?

- Completely implausible sentences can be perfectly grammatical.

Colorless green ideas sleep furiously.

- Semantic ill-formedness is something different from “crazy” sentences.

John entered the room happy.

**John entered the room intelligent.*

- **Not a syntax problem (in any obvious way)**
- **Not a plausibility problem.**



What *kinds* of things do we know about the **static representations** of language?

- Not all of grammar is audible/visible.

- teach → teacher

- bake → baker

- driver → driver

- cook → cook \emptyset (*NB the special meaning of 'cooker'*)



What *kinds* of things do we know about the **static representations of language?**

- English in particular has lots of silent grammar.



English

The snow melted



English

The snow melted

Adding a
causer

John melted the snow



English

The snow melted

Adding a
causer

John melted the snow

Adding a
benefactor

John melted **me** some snow



English

The snow melted

Adding a
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John melted the snow

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benefactor

John melted **me** some snow

Venda (Bantu language)

Mahada onoka
snow melted



English

The snow melted

Adding a
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John melted the snow

Adding a
benefactor

John melted **me** some snow

Venda (Bantu language)

Mahada onoka
snow melted

Mukasa onokisa mahada
Mukasa melted **CAUSE** snow



English

The snow melted

Adding a
causer

John melted the snow

Adding a
benefactor

John melted **me** some snow

Venda (Bantu language)

Mahada onoka
snow melted

Mukasa onokisa mahada
Mukasa melted_{CAUSE} snow

Mukasa onokisela **Katonga** mahada
Mukasa melted_{CAUSE.BEN} Katonga snow



English

The snow melted

Adding a
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English

This boy cleaned the table.



English

Actor comes first

This boy cleaned the table.



English

Actor comes first

This boy cleaned the table.

This table cleaned easily.



English

Actor comes first

This boy cleaned the table.

Actor doesn't come
first!

This table cleaned easily.



English

Actor comes first

This boy cleaned the table.

Actor doesn't come
first!

This table cleaned easily.

Finnish

Tämä poika pesi pöydän
This boy washed table



English

Actor comes first

This boy cleaned the table.

Actor doesn't come first!

This table cleaned easily.

Finnish

Tämä poika pesi pöydän
This boy washed table

Tämä pöytä peseytyi helposti
This table cleaned_{REFL} easily



What *kinds* of things do we know about the **static representations** of language?

- Content vs. function words

The boy s pick ed up a blend er from the store .

* The ____ s ____ ing up a ____ er from the ____ .

Grammaticality depends on function words.

We can detect ungrammaticality without understanding the content words of a sentence.



What *kinds* of things do we know about the **static representations** of language?

- Language is generative and productive. Not memorization.
- The meanings of sentences must be largely predictable from the meanings of the parts.
 - **So in order to explain why sentences mean what they do, we must understand what the parts mean.**



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What *kinds* of things do we know about the **language processing**?

- When we hear or see words, lots of word representations get activated.

Semantic priming:

LION primes TIGER

Mediated semantic priming:

LION primes STRIPE (via TIGER)

Phonological priming:

BULLET both primes and inhibits BULL



What *kinds* of things do we know about the **language processing**?

- Frequency matters. We're good at doing things that we do a lot.
 - **Much work on lexical frequency.**
 - **Structural frequency a tricky issue.**



What *kinds* of things do we know about the **language processing**?

- Long distance dependencies are hard.

The juice that the child spilled _ stained the rug.

The child spilled the juice that _ stained the rug.

- Due to frequency? Here the harder sentence type is the more frequent one:

*The postman delivered **the mail** dirty and shredded after the rainstorm.*

- less frequent but easier

***The postman** delivered the mail dirty and irritated after the rainstorm.*

- more frequent but harder



What *kinds* of things do we know about the **language processing**?

- The parser prefers to add material to an ongoing clause rather than starting a new one.

“Garden-path” sentences:



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“Garden-path” sentences:

While



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“Garden-path” sentences:

While the man



What *kinds* of things do we know about the **language processing**?

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“Garden-path” sentences:

While the man hunted



What *kinds* of things do we know about the **language processing**?

- The parser prefers to add material to an ongoing clause rather than starting a new one.

“Garden-path” sentences:

While the man hunted the deer



What *kinds* of things do we know about the **language processing**?

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“Garden-path” sentences:

While the man hunted the deer ran



What *kinds* of things do we know about the **language processing**?

- The parser prefers to add material to an ongoing clause rather than starting a new one.

“Garden-path” sentences:

While the man hunted the deer ran into the woods.



What *kinds* of things do we know about the **language processing**?

- The parser prefers to add material to an ongoing clause rather than starting a new one.

“Garden-path” sentences:

While the man hunted the deer ran into the woods.

While Anna dressed the baby spit up on the bed.



What *kinds* of things do we know about the **language processing**?

- Non-compositional meanings are hard.

Compositional:

The author began writing a book.

Noncompositional:

The author began a book.



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What *kinds* of things do we know about the **neurobiology of language**?

- By far the most common method in neurolinguistics has been to surprise the brain in various ways. When you surprise the brain, it generally gives you some sort of robust response.
- What the brain is surprised by can be useful way to find out what the brain knows.



What *kinds* of things do we know about the **neurobiology of language**?

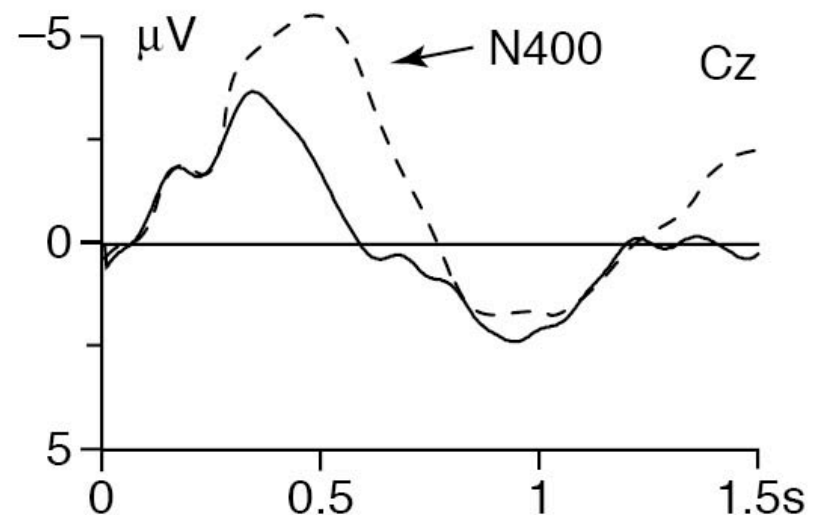
- Auditory cortex has access to categorical representations of sounds.
 - **There's a surprise response, called the "Mismatch Negativity," that is elicited when you habituate the listener to one sound category and then suddenly cross a perceptual boundary.**
 - Handy tool for asking all sorts of questions about categorization.

What *kinds* of things do we know about the **neurobiology of language**?

- The brain responds to implausibility in a robust manner.

— Das Hemd wurde gebügelt.
The shirt was 'ironed'.

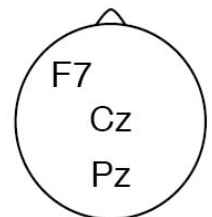
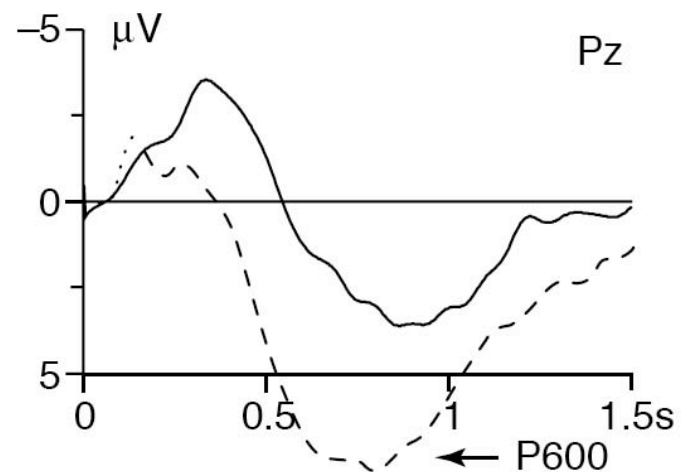
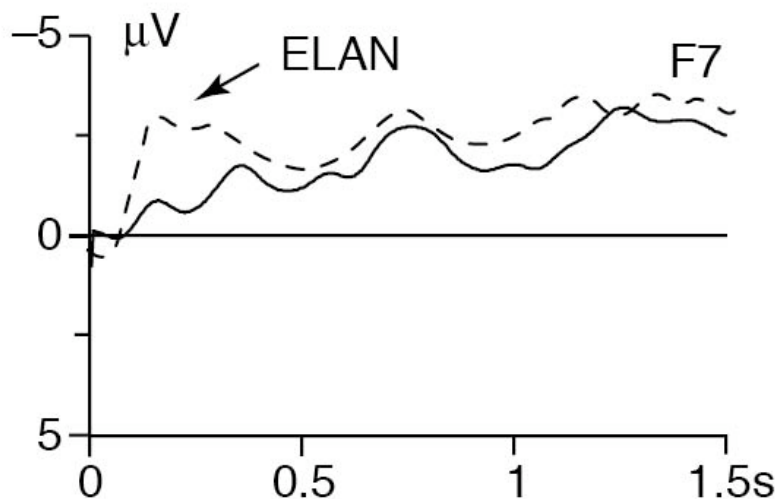
-- Das Gewitter wurde gebügelt.
The thunderstorm was ironed.



What *kinds* of things do we know about the **neurobiology of language**?

- The brain responds to ungrammaticality in a robust manner.

- Das Hemd wurde bebügelt.
The shirt was 'ironed'.
- Die Bluse wurde am gebügelt
The blouse was on ironed.





What *kinds* of things do we know about the **neurobiology of language**?

- There is an area in the brain that is specifically tuned to processing letters
- It's much less clear whether there is an area that is specifically tuned to processing speech.



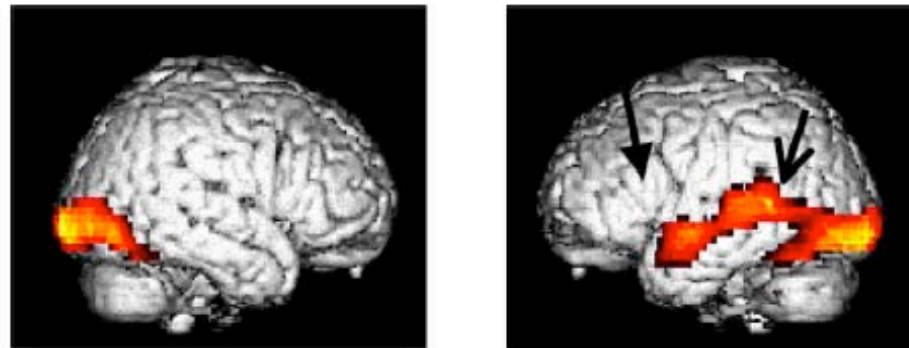
What *kinds* of things do we know about the **neurobiology of language**?

- As a result of stroke, it is possible to suffer selective damage to your ability to name entities that belong to a very narrow semantic field, like vegetables.
- This sort of thing is rather mysterious from the point of view of theoretical linguistics.

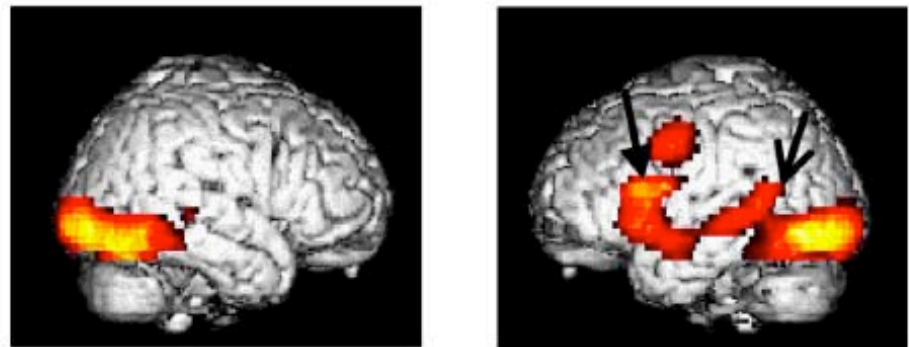


What *kinds* of things do we know about the **neurobiology of language**?

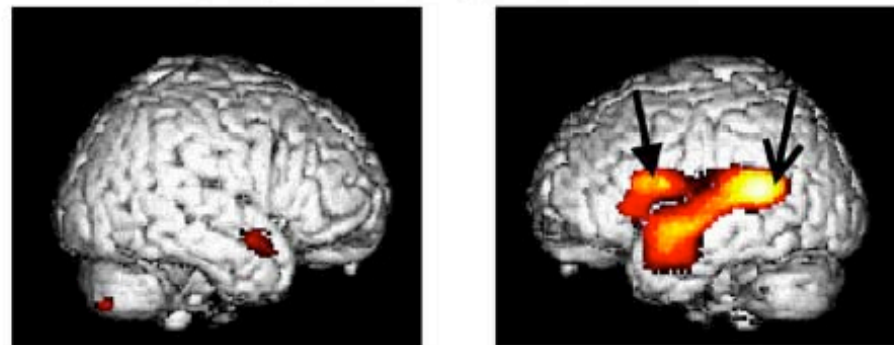
- There is an area, called “Broca’s area,” that lights up pretty much whenever syntactic structures are difficult, but when syntactic computation is easy, the area seems to be napping.
 - **If this area performs “syntax,” shouldn’t it always light up when syntax is computed (even if easy)?**



(A) Simple sentences vs. passive fixation



(B) Complex sentences – passive fixation control



(C) Complex sentences – non-linguistic visual control



We have no idea...

- How syntactic constituency is represented in the brain.
- Whether and how the brain represents the silent ‘er’ of the noun *cook* or the silent causer and benefactive morphemes of *melt* in *John melted me some snow*.
- How the brain represents the dependency of between a moved element and its trace.



But we do have some idea of...

- Where LION primes TIGER in the brain.
- What happens in the brain when meaning isn't compositional (very recent results!).
- Which areas of the brain know about phonological categories.



Granularity problem

- There is a huge difference in the level of detail in analysis in theoretical linguistics and the brain sciences.
- The difference between psycholinguistics and the brain sciences isn't as big.

What does it take to understand language?

Modality dependent

Listening

- Acoustic-phonemic analysis

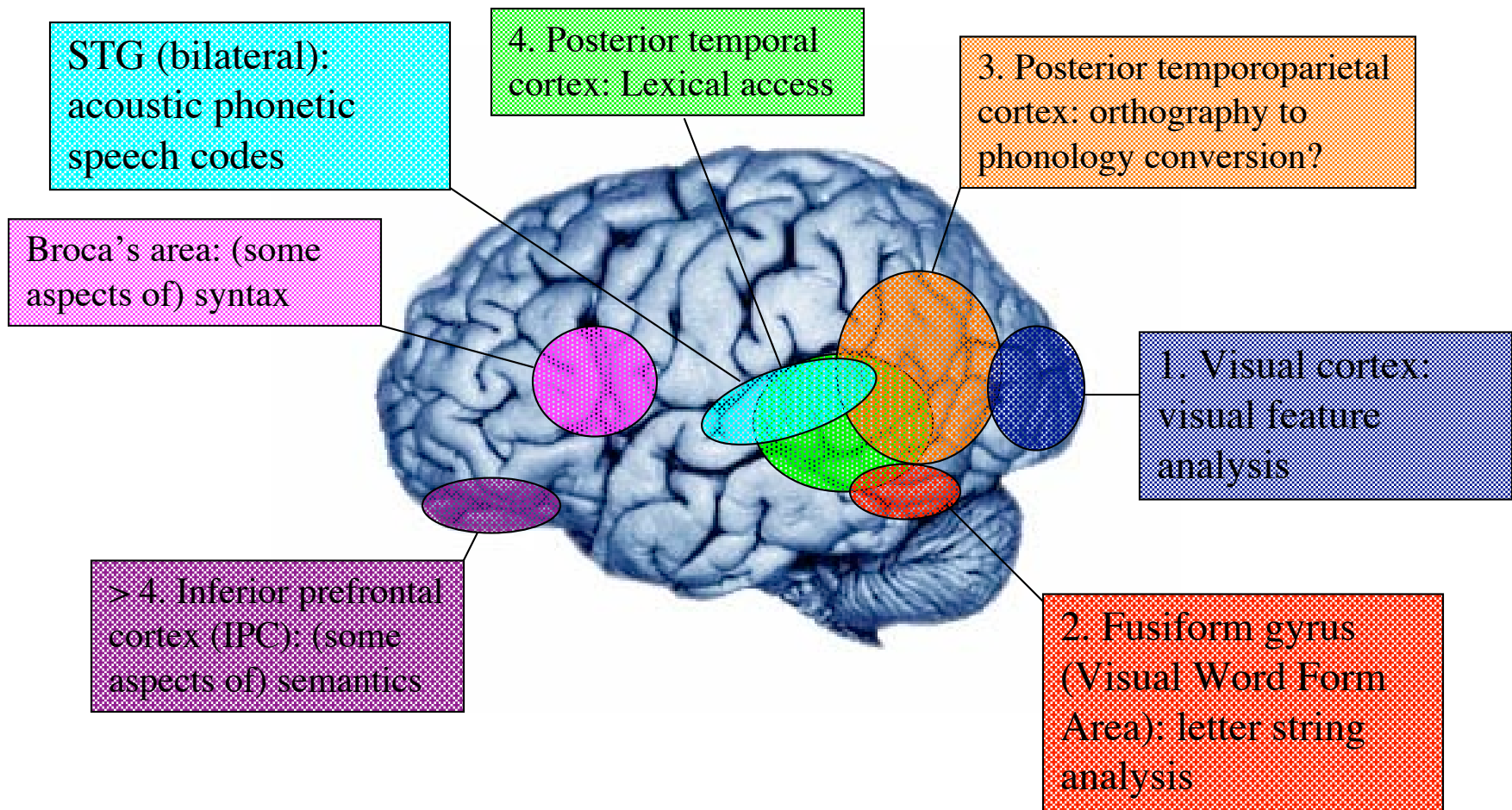
Reading

- Letter-string analysis
 - (Orthography to phonology conversion)
-

Modality independent

- Activation of sound-meaning connections (lemmas, or roots: dog, run)
- Activation of grammatical morphemes (-ing, -ed, that, the, a)
- Combining elementary building blocks into complex syntactic and semantic representations.

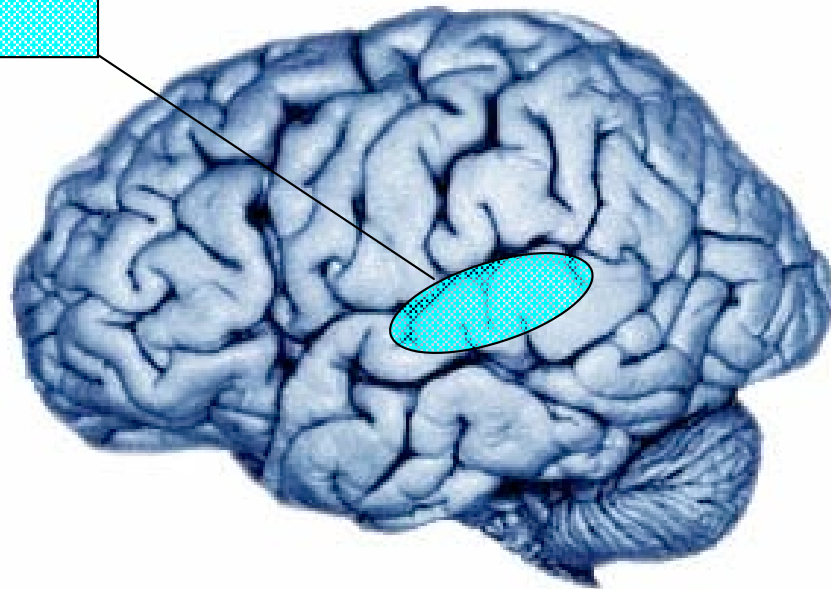
The model we will evaluate



■ STG

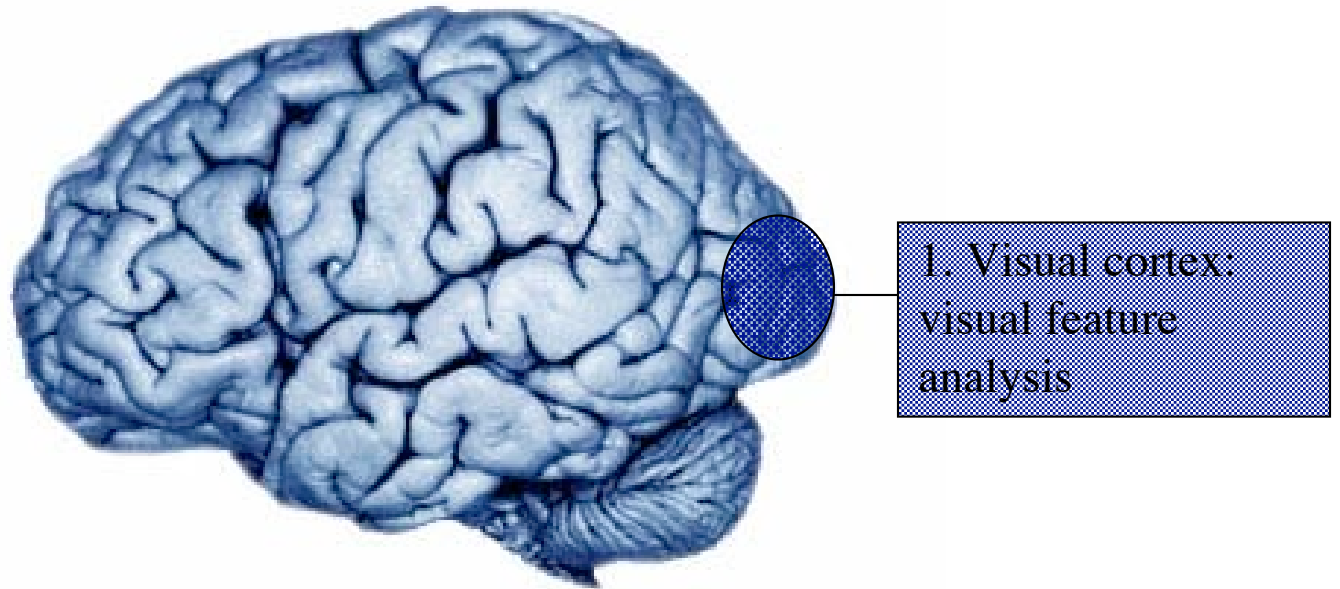
- **At 100ms: Intensity and frequency of stimulus, phonetic identity of a vowel**
- **By 200ms: phonological categorization has occurred.**

STG (bilateral):
acoustic phonetic
speech codes



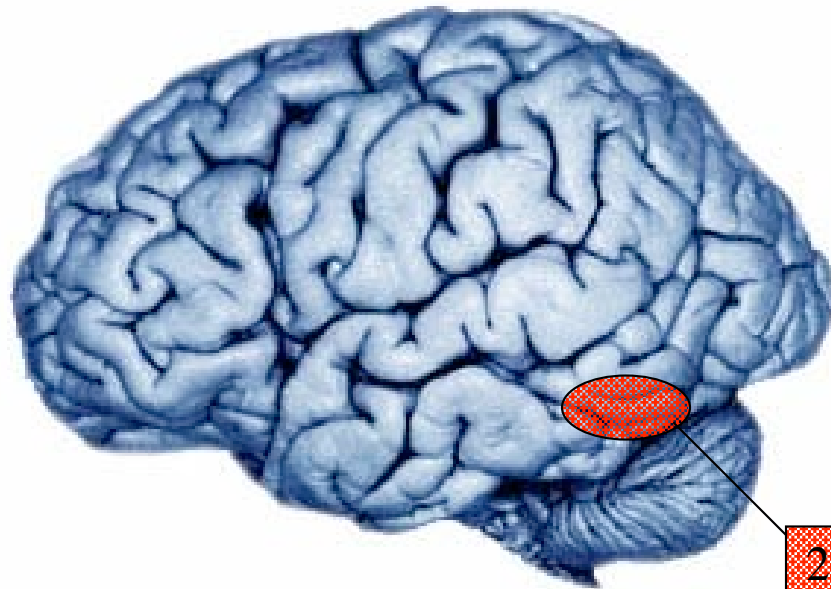
- Visual cortex:

- **Nonlinguistic, physical stimulus properties:
luminance, stimulus length**



- Left fusiform gyrus:

- **Stronger activation for letter strings.**
- **Abnormal in dyslexics.**

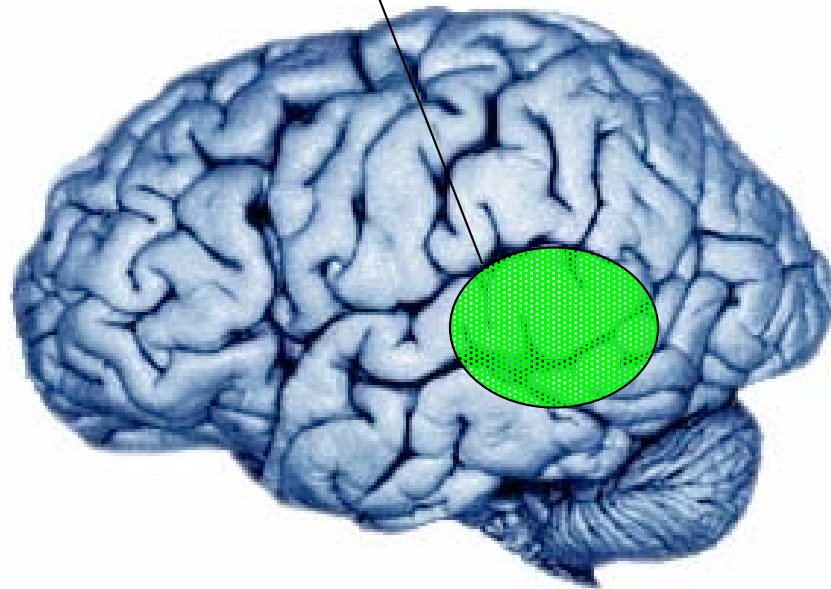


2. Fusiform gyrus
(Visual Word Form
Area): letter string
analysis

- Left STG, “Wernicke’s area”:

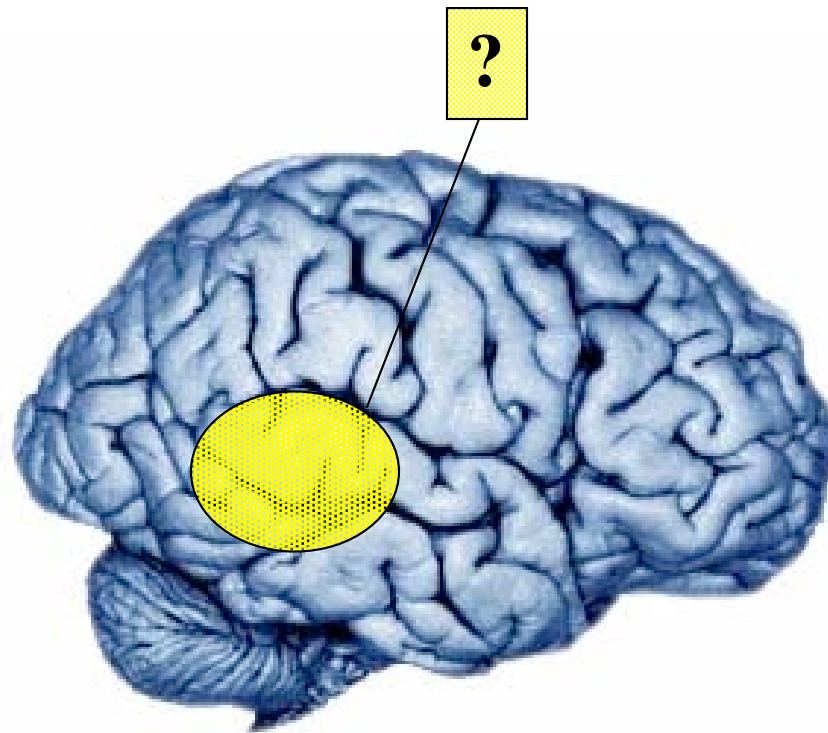
- **Lexical frequency, repetition, semantic and phonological relatedness, cumulative morpheme frequency, sense-relatedness in polysemy.**

4. Posterior temporal cortex: Lexical access



- RH temporal & parietal areas:

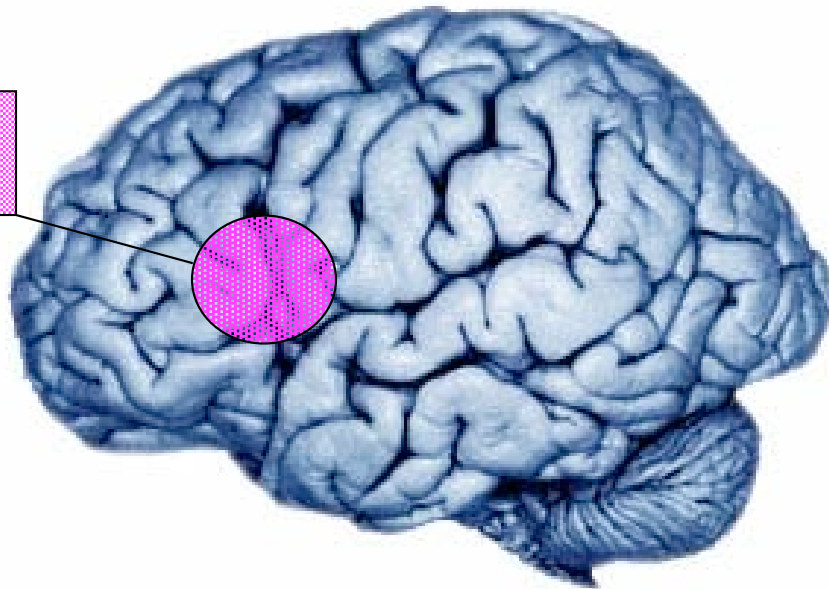
- **Sense-relatedness (inhibitory effect), semantic relatedness (facilitory), supports non-literal interpretation**



■ Broca's area

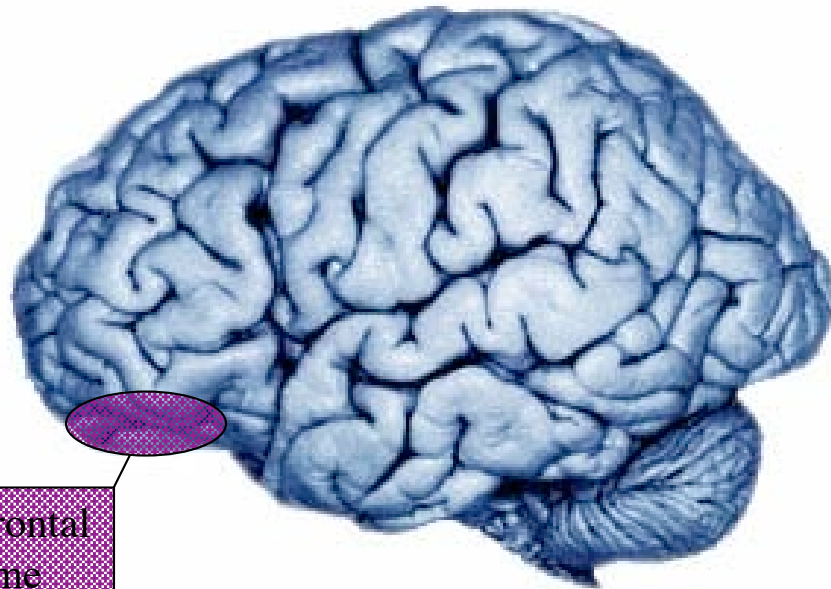
- **Difficult syntactic structures, grammaticality judgments (as opposed to other types of judgments).**
- **Semantic competition/interference in non-syntactic tasks.**

Broca's area: (some aspects of) syntax



- Inferior frontal areas:

- **Noncompositional semantic interpretation(?)**



> 4. Inferior prefrontal cortex (IPC): (some aspects of) semantics