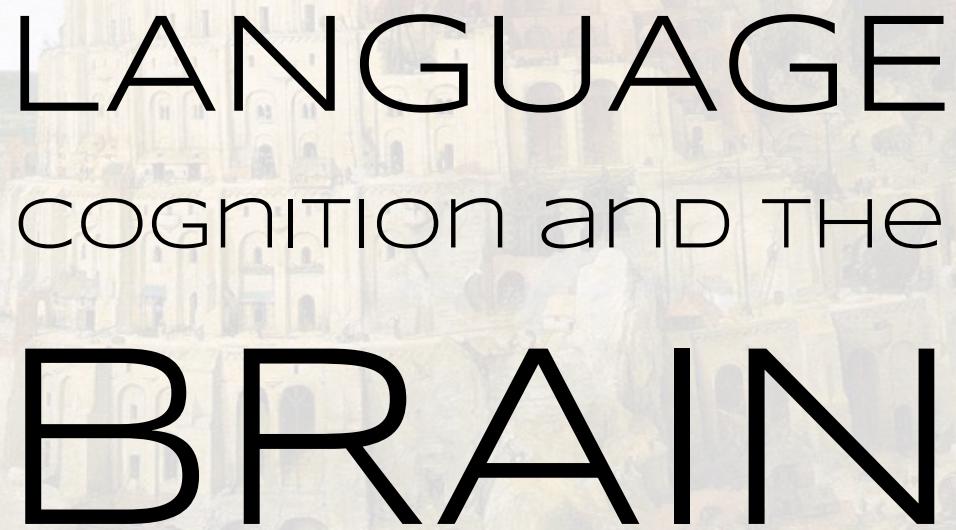


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EXPerimental PSYCHOLOGY





LANGUAGE COGNITION AND THE BRAIN



outline

Defining Language

Levels of Language Analysis

Aphasia, Lesions, and
Houses

Language Related
Asymmetries

Newer **Methods** for Studying
Language & Brain

"One of those rare
smart and funny books."
—Penn Jillette

**Watch
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How to swear effectively,
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Sterling Johnson

(and a Distinguished Panel of Experts)

WHAT IS LANGUAGE?

There is **no** universal agreement - Difficult to define

Some critical **properties**
(from Clark & Clark, 1977)

Some **design features**
(from Hockett, 1963)



CRITICAL PROPERTIES

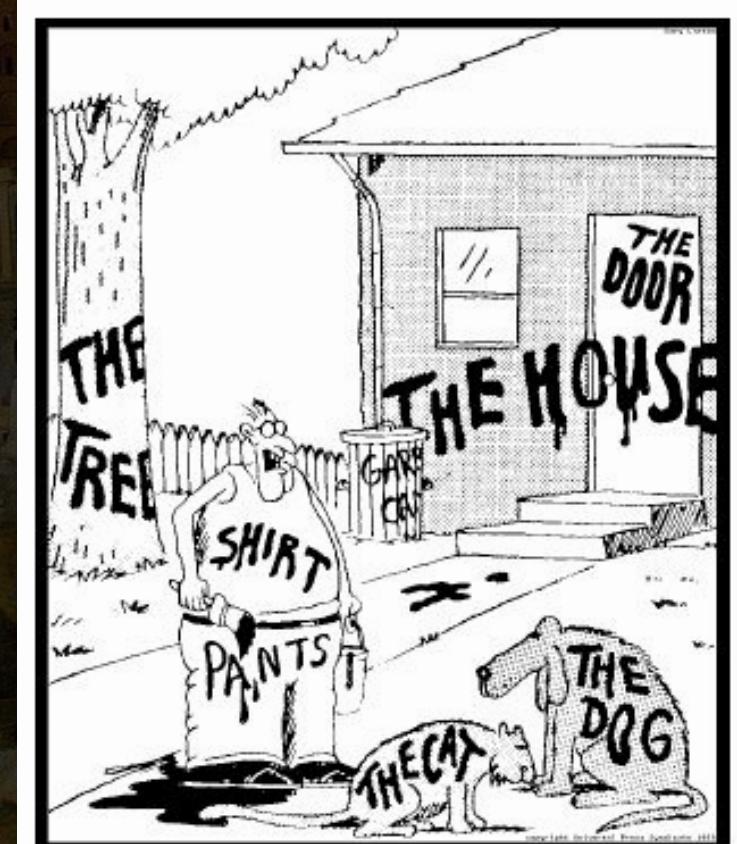
Communicative

Arbitrary - Relationship of elements in language and their meaning

Structured - Pattern is not arbitrary

Generative - Put together in new, limitless ways

Dynamic - Changing (new words, new rules)



*"Now! That should clear up
a few things around here!"*

DESIGN FEATURES

13 features - Non-human primates have first **9** but only humans have:

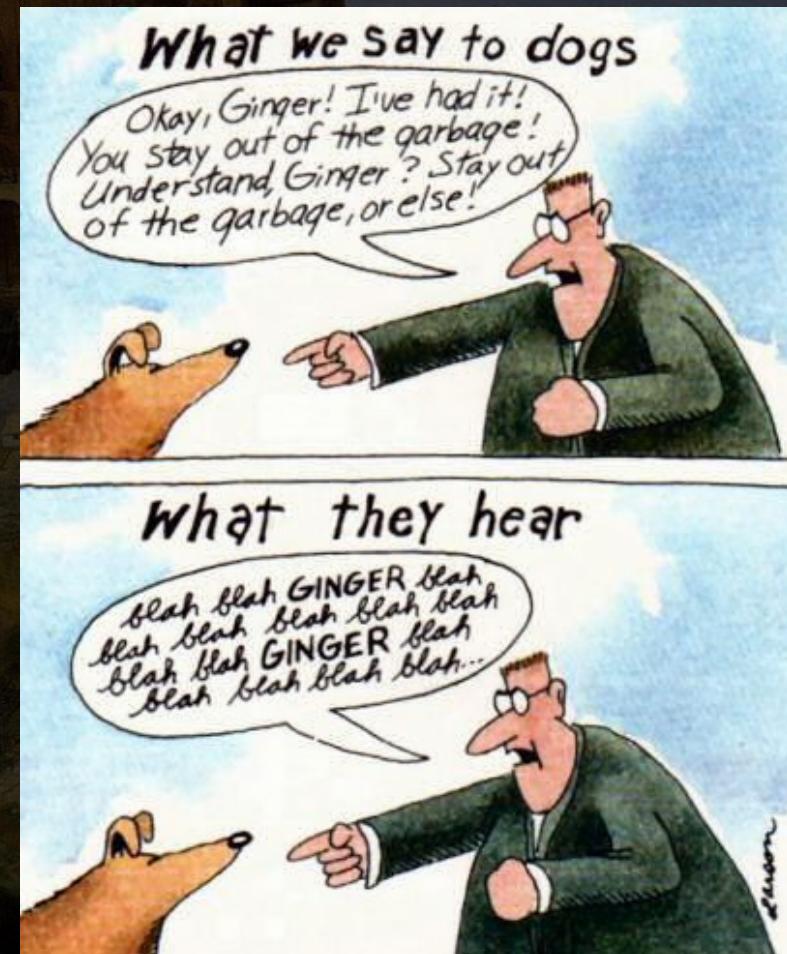
10. **Displacement** - Refer to things removed in time & space

11. **Productivity** - Create never-before-heard utterances that others understand w/ novel meanings

12. **Cultural transmission** - Not inborn (feral children)

13. **Duality of patterning** - Recombine units into near infinite number of sentences.

But what about Kanzi and Alex?



LANGUAGE - WHAT'S THE USE?

LANGUAGE, n. The music with which we charm the serpents guarding another's treasure.

Ambrose Bierce
The Devil's Dictionary

Language is for doing things

Herbert H. Clark
Using Language

SO...WITH MY HEARTFELT APOLOGIES FOR HIS TERMINOLOGY, HERE IS AN EXPLANATION OF MR. JAKOBSEN'S SIX FUNCTIONS OF LANGUAGE:

EMOTIVE ° THIS REFERS TO UTTERANCES THAT EXPRESS EMOTION - EXPRESS, NOT DESCRIBE - SUCH AS:



CONATIVE ° EXPRESSIONS SEEK TO PRODUCE BEHAVIOR.



PHATIC ° EXPRESSIONS ARE VERBAL FEEDBACK THAT SIGNAL SOMEONE THAT YOU ARE LISTENING.



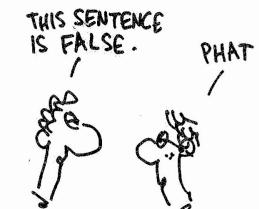
POETIC ° HERE MEANING IS SECONDARY, AND THE QUALITY, SOUND, OR TEXTURE OF LANGUAGE ITSELF CAME FIRST.



REFERENTIAL ° THIS IS THE ONE YOU WOULD PROBABLY THINK OF FIRST. REFERENTIAL SENTENCES REFER TO THE OUTSIDE (OR INSIDE) WORLD.



METALINGUISTIC: LANGUAGE TALKING ABOUT LANGUAGE.



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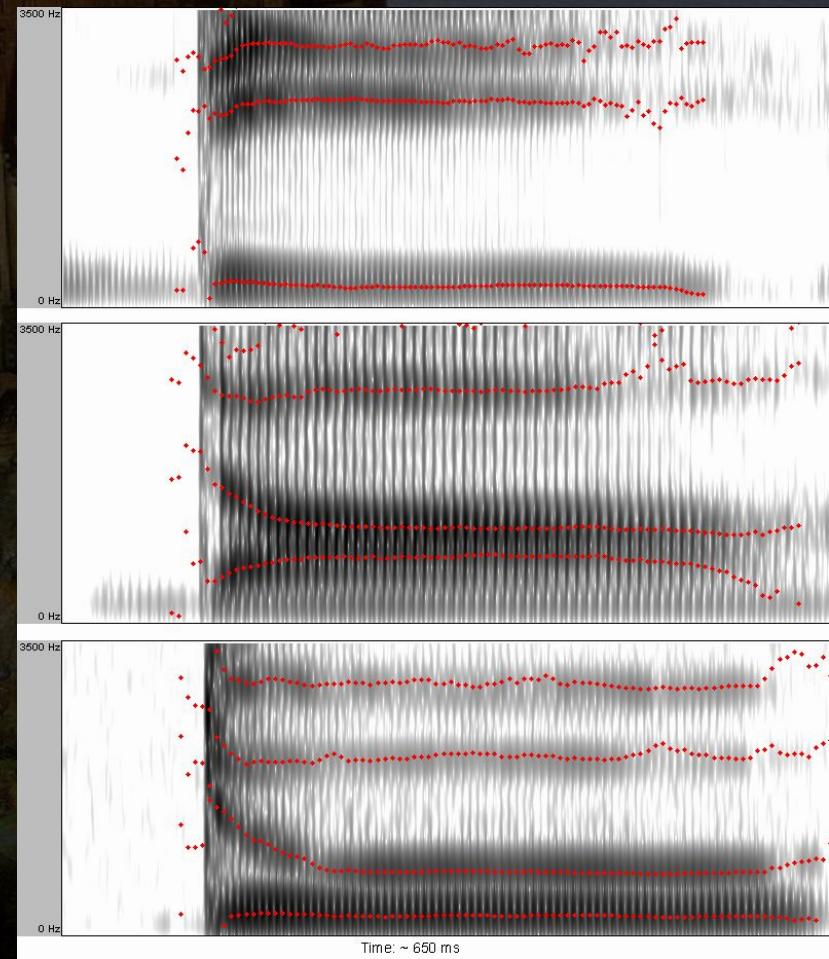
(and a Distinguished Panel of Experts)

LEVELS OF ANALYSIS: PHONOLOGY

Units: Typically sounds,
phonemes, syllables

Speech perception

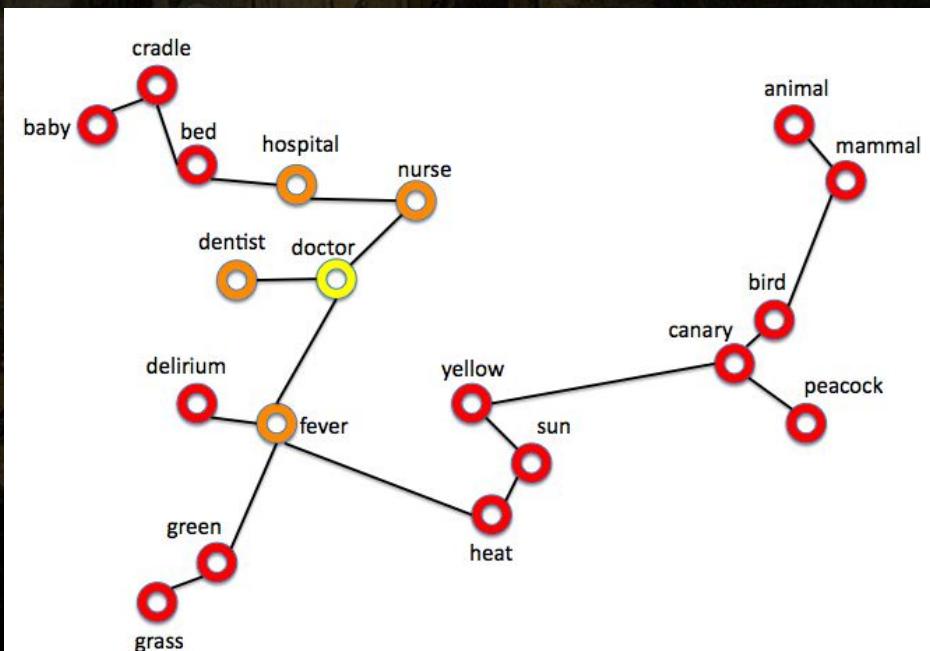
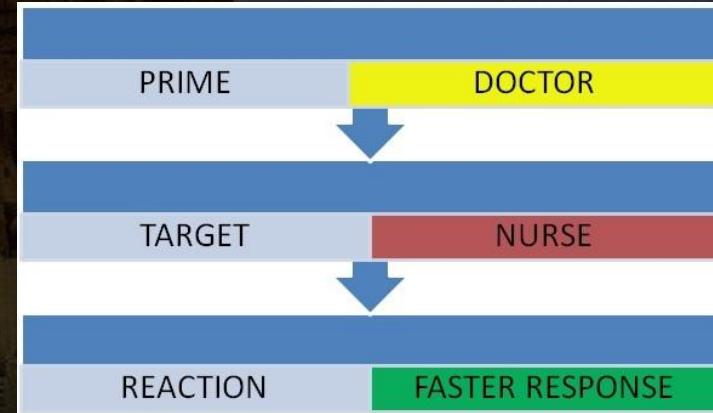
Spectrograms of Dee, Dah,
Doo



LEVELS OF ANALYSIS: semantics

Units: Typically lexical (word)

Semantic priming

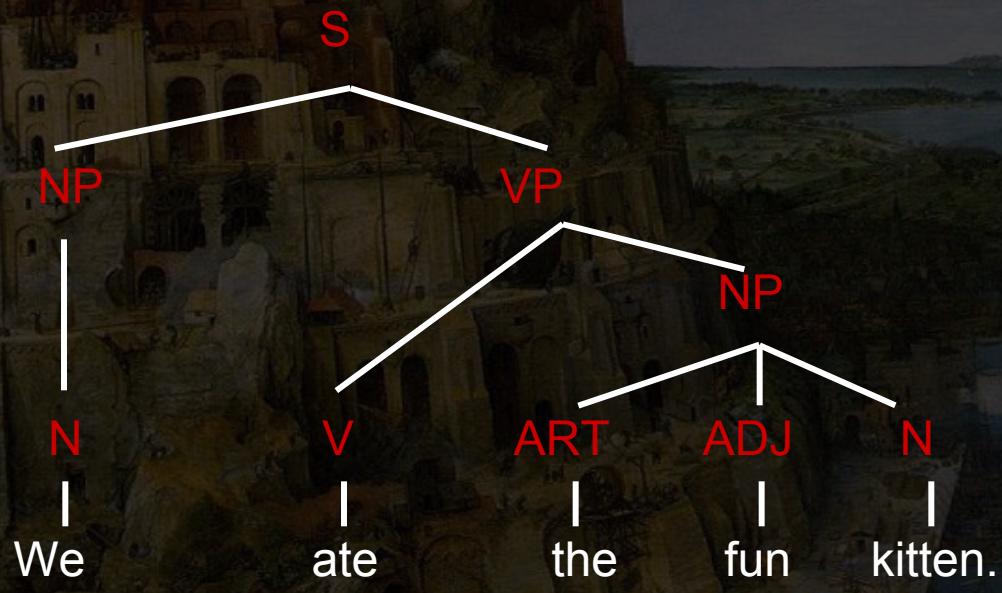


LEVELS OF ANALYSIS: Grammar

Units: Typically sentence

Syntax -
Hierarchical structure

Combinatorial
rules or statistical
regularities



LEVELS OF ANALYSIS: ORTHOGRAPHY

Reading Written words

	oracle bone jiaguwen	greater seal dazhuan	lesser seal xiaozhuan	clerkly script lishu	standard script kaishu	running script xingshu	cursive script caoshu	modern simplified jiantizi
rén (*nin) human	人	人	人	人	人	人	人	人
nǚ (*nra?) woman	女	女	女	女	女	女	女	女
ěr (*nha?) ear	耳	耳	耳	耳	耳	耳	耳	耳
mǎ (*mrā?) horse	馬	馬	馬	馬	馬	馬	馬	馬
yú (*ŋha) fish	魚	魚	魚	魚	魚	魚	魚	魚
shān (*srān) mountain	山	山	山	山	山	山	山	山
rì (*nit) sun	日	日	日	日	日	日	日	日
yuè (*ŋöt) moon	月	月	月	月	月	月	月	月
yǔ (*wha?) rain	雨	雨	雨	雨	雨	雨	雨	雨
yún (*wən) cloud	云	云	云	云	云	云	云	云



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PAUL BROCA, TAN & HIS AREA

LeBorgne - difficulty speaking after stroke (said "Tan") but comprehended speech

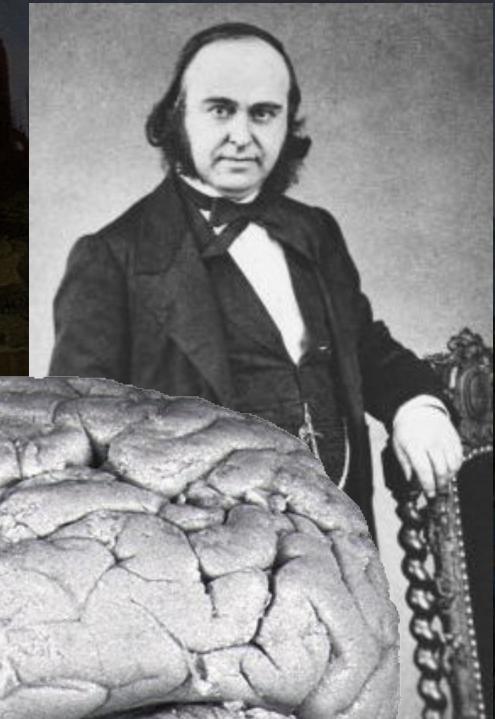
Motor control of face, mouth & tongue not compromised

Suggested lesion had a specific effect on **language control**

Become known as '**Broca's aphasia**'
(A.K.A. motor or nonfluent aphasia)

Pars opercularis (BA44) and pars triangularis (BA45) of the **inferior frontal gyrus (IFG)** are often called 'Broca's area'

Example patient



KARL WERNICKE & HIS Area

Patients lost ability to **comprehend & produce meaningful speech** (word salad; despite normal articulation, grammar & prosody)

Became known as '**Wernicke's aphasia**' (or receptive, fluent or sensory aphasia)

Damage often around **posterior superior temporal** cortex b/n Heschl's & angular gyrus

Proposed **circuit** where 'Wernicke's area' plays role in comprehension & 'Broca's area' in production

Example patient

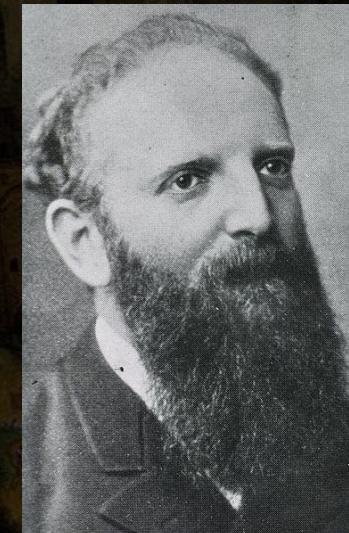
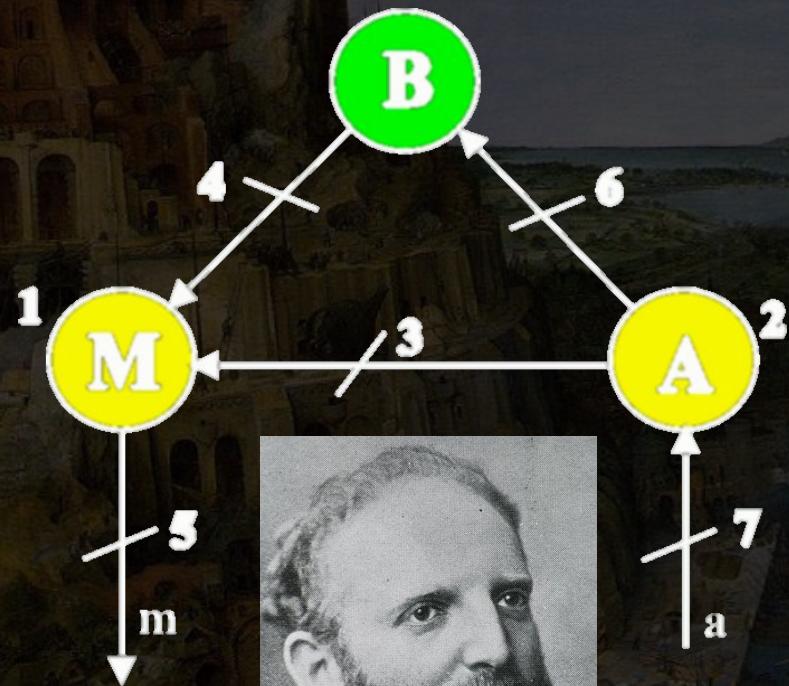


LUDWIG LICHTHEIM & HIS CONNECTIONS

Suggested lesions to Broca's or Wernicke's areas or their **disconnection** account for language deficits after lesion

The House (Lichtheim, 1885):

'The reflex arc consists in an afferent branch aA, which transmits the acoustic impressions to A; and an efferent branch Mm, which conducts the impulses from M to the organs of speech; and is completed by the commissure binding together A and M. When intelligence of the imitated sounds is superimposed, a connection is established between the auditory centre A, and the part where concepts are elaborated, B.'



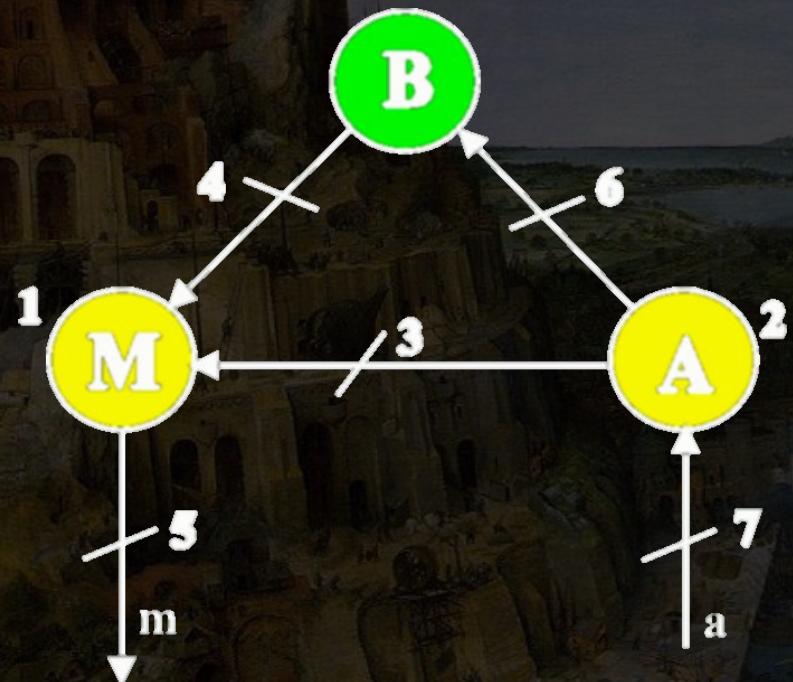
CONDUCTION APHASIA

Lesion of fibers connecting A and M (3)

Comparison with Broca's and Wernicke's aphasia: **Speech fluent and comprehension good**

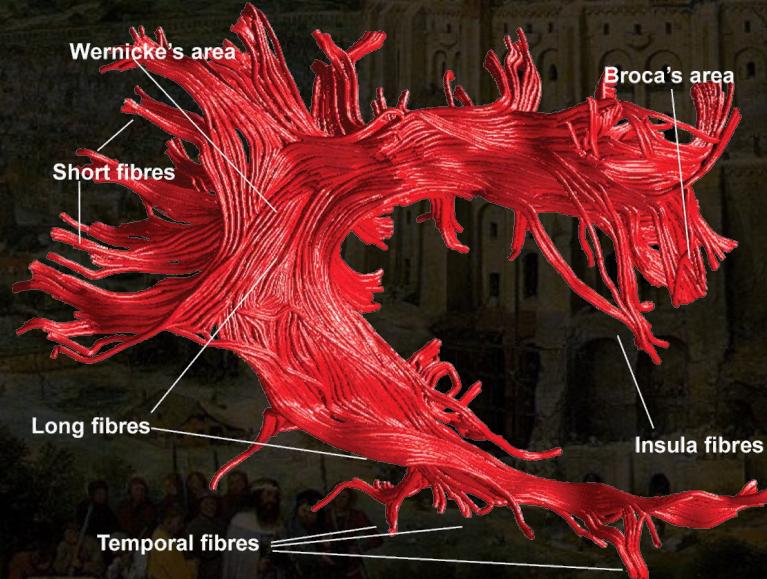
But - **Difficulty repeating words**

Lots of repetition substitution / omission of words



THE Arcuate Fasciculus

That is, the 'fibers connecting A and M'

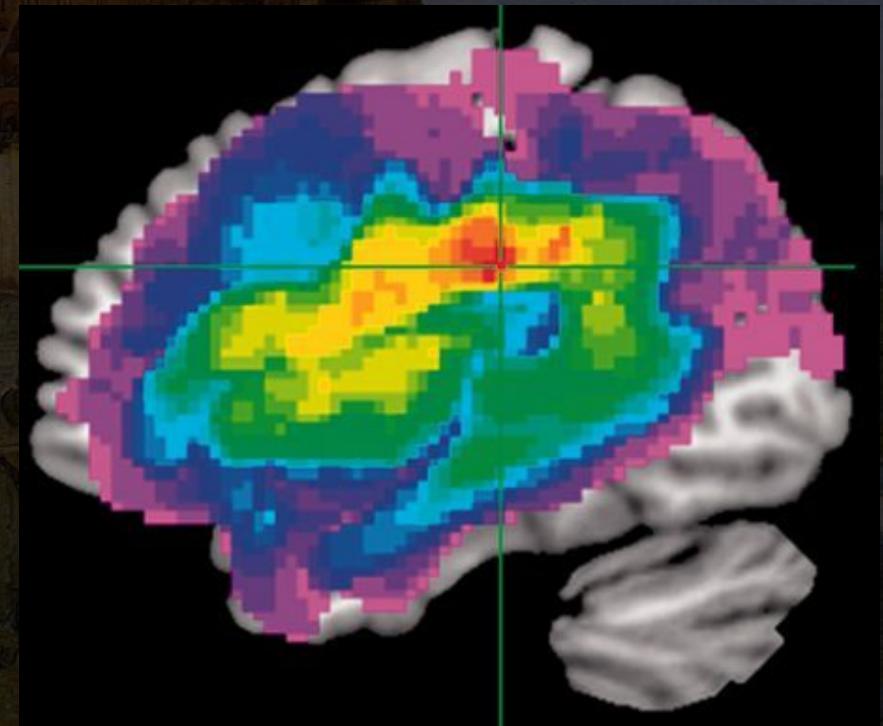


APHASIAS

Many types

Pure word deafness - Selective word-comprehension deficit but can read; able to recognize non-verbal sounds

Global aphasia - Impaired comprehension and production, residual overlearned speech



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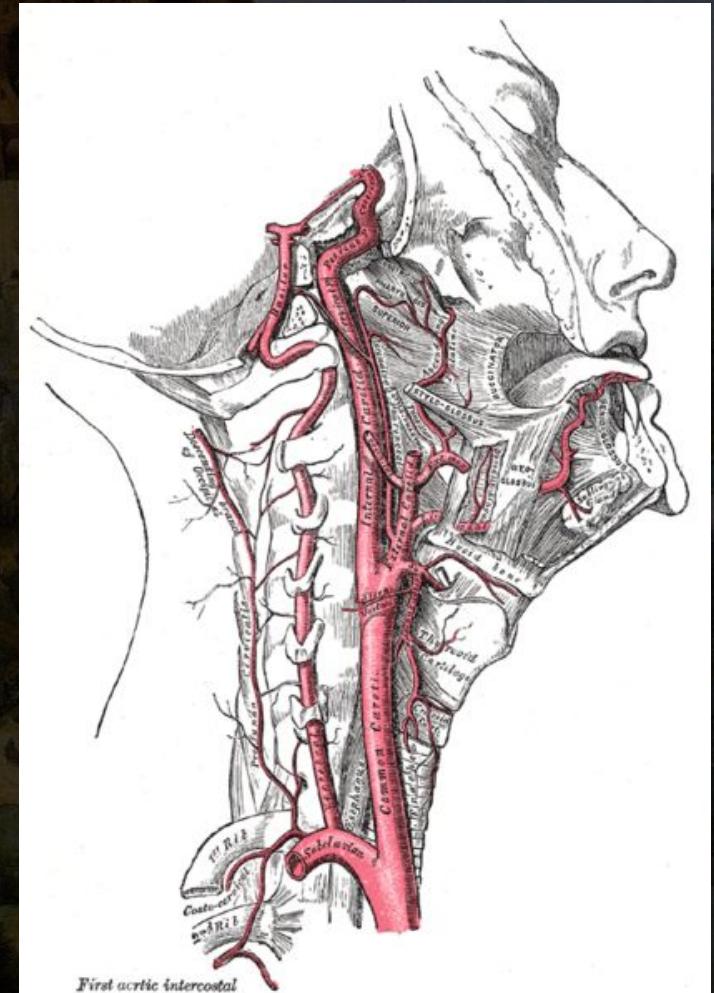
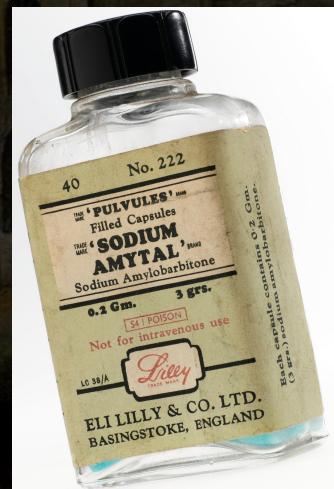
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wada test for Laterality

Used to determine
hemisphere dominant
for speech

Most results suggest
left language
dominance

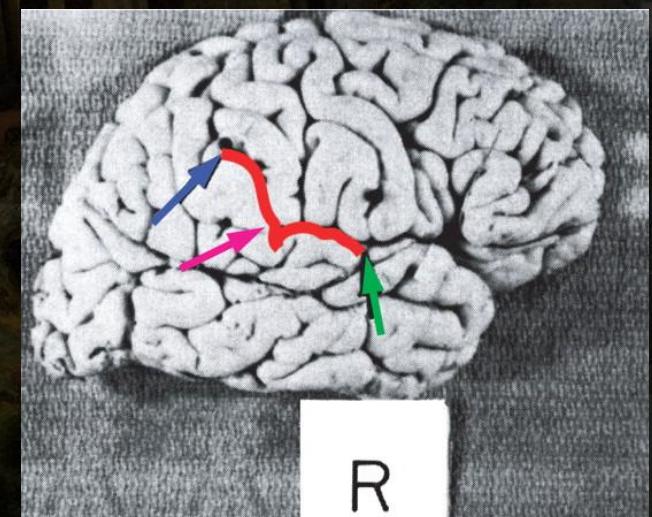
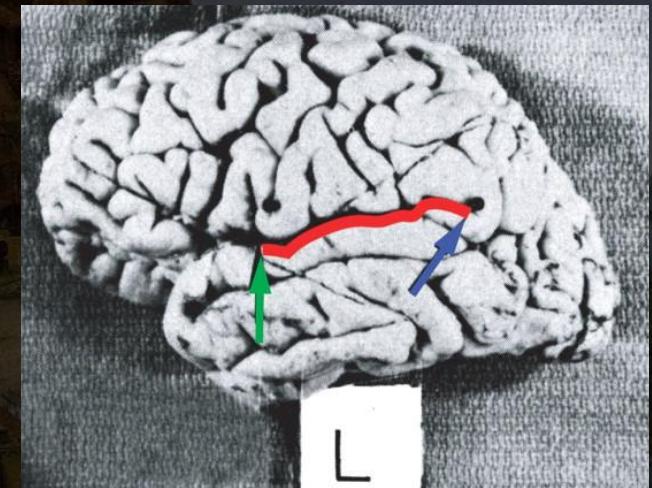
Functional asymmetry
90% right-handed



ANATOMICAL ASYMMETRY & LANGUAGE

Left Sylvian fissure
longer & less steep
than right

Geschwind & Levitsky -
Left planum temporal
larger than right in **65%**
cases



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NEWER METHODS FOR STUDYING LANGUAGE

Old methods - Correlate language deficits with postmortem analysis of brain damage

More recent techniques (*in vivo*):

Electrical brain **stimulation**

Neuroimaging: PET and fMRI



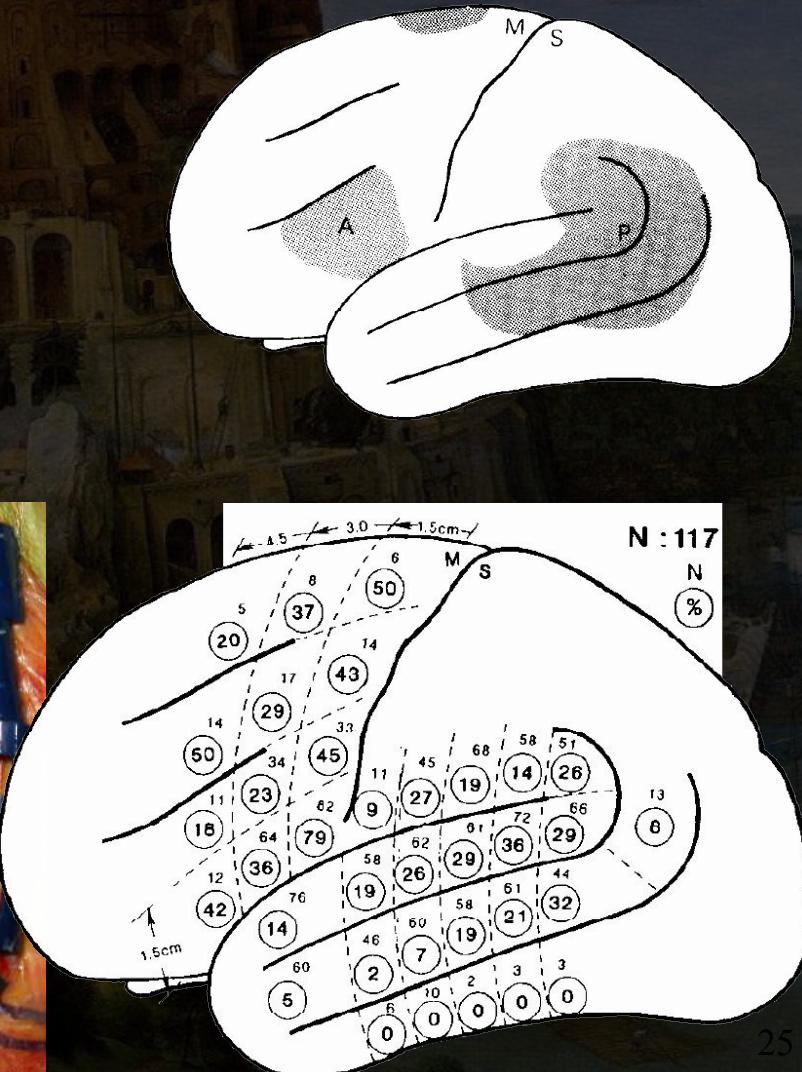
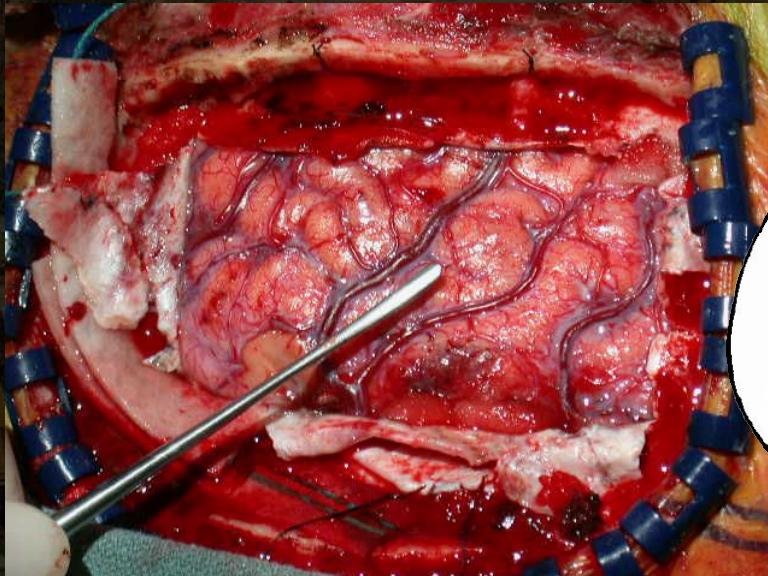
STIMULATING THE BRAIN ELECTRICALLY

George Ojemann

Top Right - 'language in the traditional textbook model'

Bottom Right - 'Variability in localization of sites... circled number indicates the percentage of those subjects in whom naming errors were evoked'

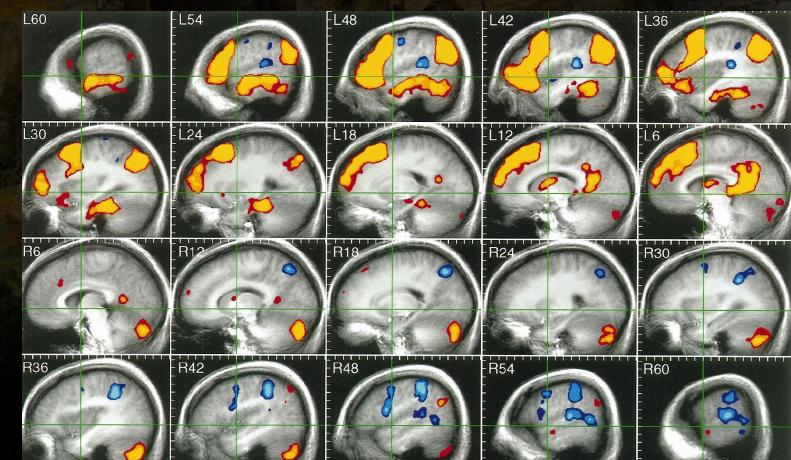
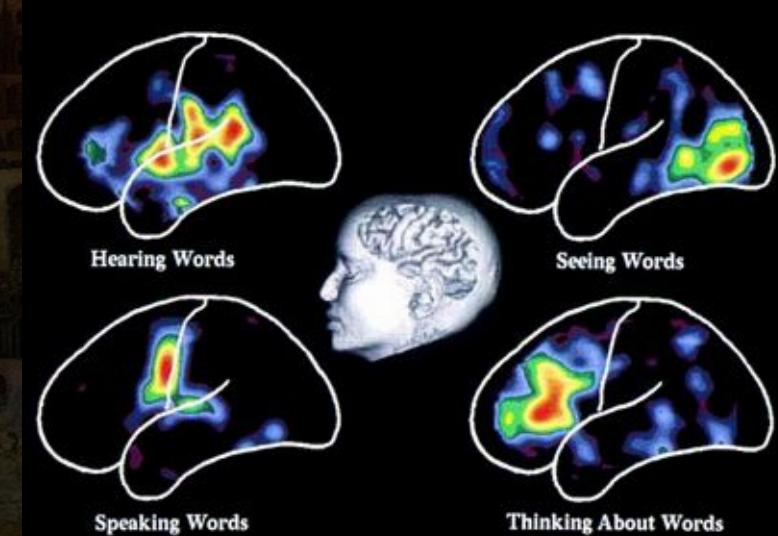
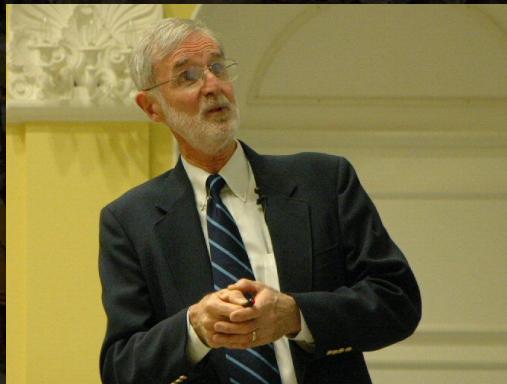
Yum:



PET and fMRI

PET and fMRI activate brain areas consistent with temporal and parietal language areas

'Areas that were activated more strongly by the semantic decision task than by the tone task were defined as language areas and were found almost exclusively in the left hemisphere.'



wernicke-geschwind model

Broca's area -
Production

Wernicke's area -
Comprehension

Arcuate Fasciculus

Angular gyrus
(reading)

Problems with model?

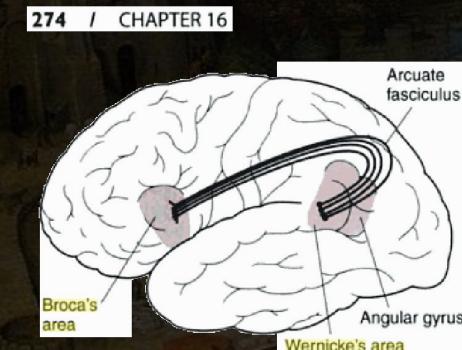
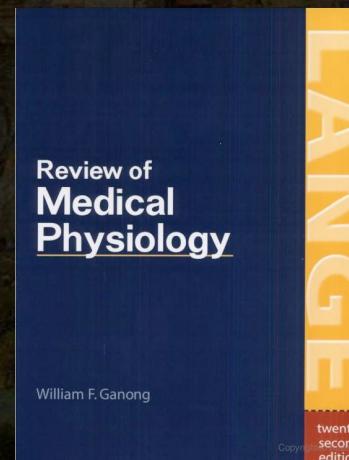
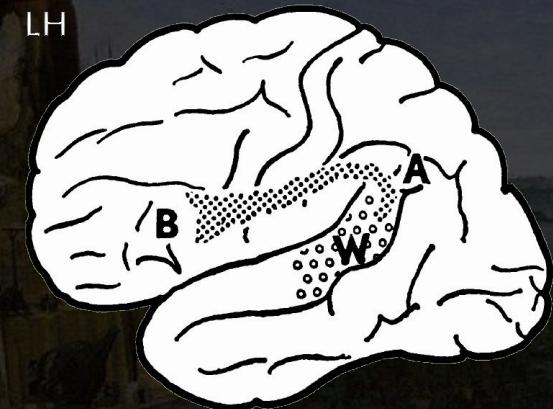


Figure 16-6. Location of some of the areas that in the categorical hemisphere are concerned with language functions.

INTERMISSION



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

No clear relationship between Broca's Area and speech **production**

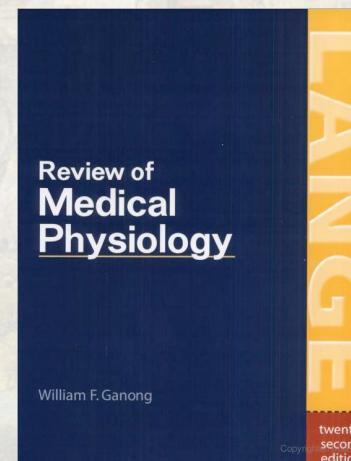
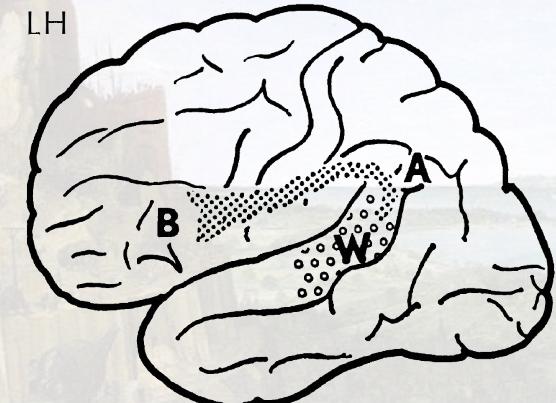
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Language is not so **left lateralized**

Words are distributed throughout the **whole brain**

Because **language is complex**, passive and bottom-up models do not work



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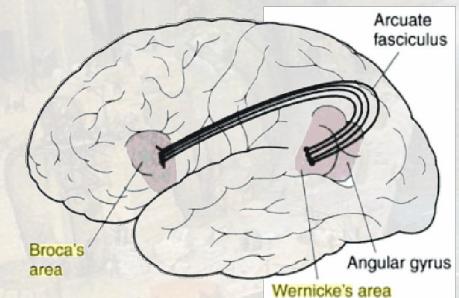


Figure 16-6. Location of some of the areas that in the categorical hemisphere are concerned with language functions.

PROBLEMS WITH 'BROCA'S AREA'

Lesions to Broca's area **alone do not** result in a Broca's aphasia

Broca's aphasic patients **do not** necessarily have lesions in Broca's area

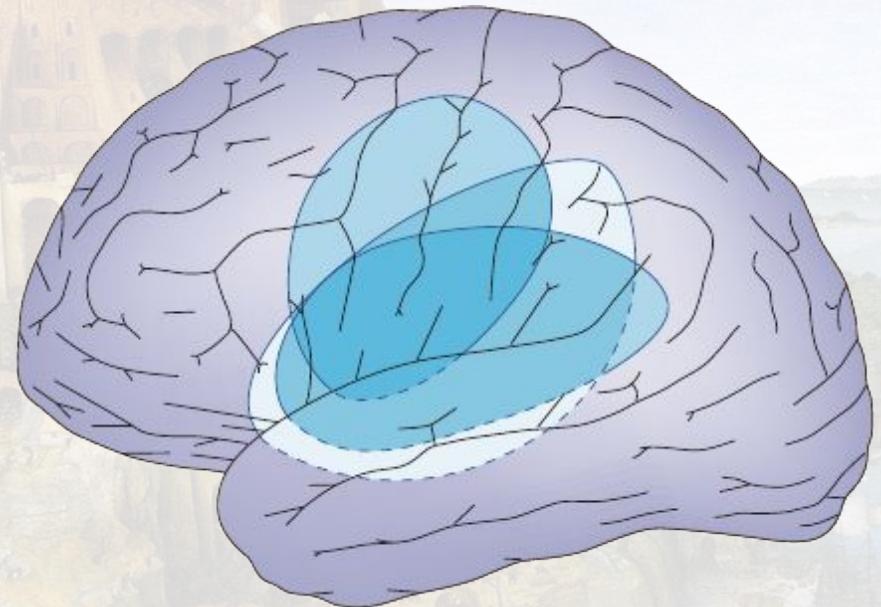
Lesions to Broca's area alone produces only a **transient mutism** that resolves w/in 3–6 weeks

Patients with Broca's aphasia & patients with damage to Broca's often have **comprehension deficits**

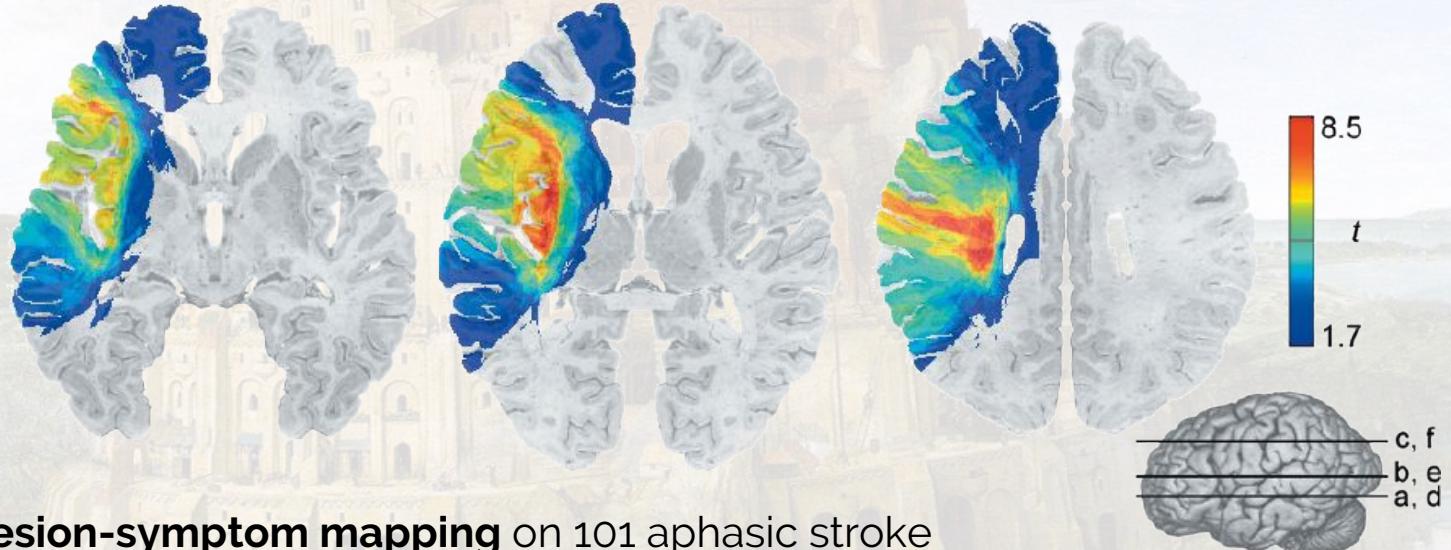
Functional imaging has **inconsistently activated** this area during production

Broca's area activated in functional imaging studies of **speech perception & language comprehension**

And activated in all sorts of **non-linguistic tasks**



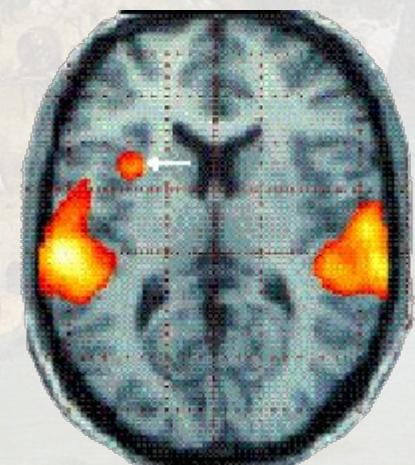
PROBLEMS WITH 'BROCA'S AREA'



Voxel-based **lesion-symptom mapping** on 101 aphasic stroke patients.

Lesions within the **insula and deep parietal white matter** had the most impact on measures of speech production or fluency.

Anterior insula has also been implicated as important for fluency in neuroimaging studies (e.g. Wise *et al.*, 1999; Blank *et al.*, 2002).



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

No clear relationship between Broca's Area and speech **production**

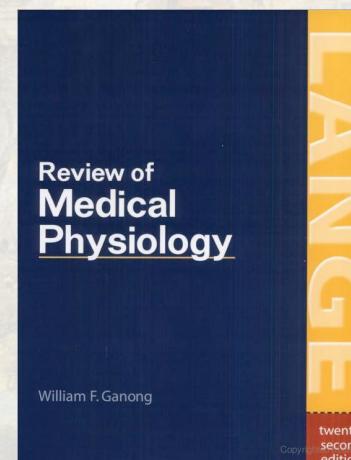
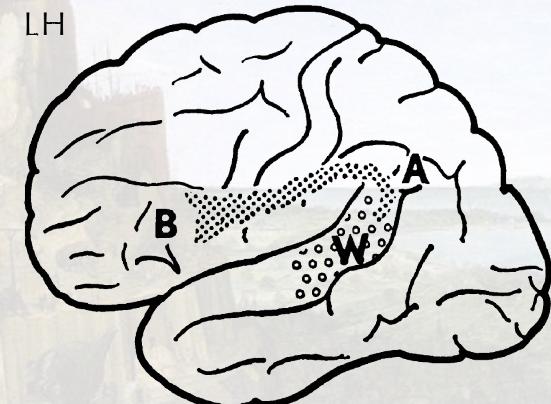
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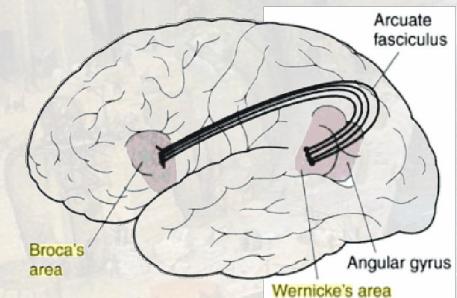


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PROBLEMS WITH 'WERNICKE'S AREA'

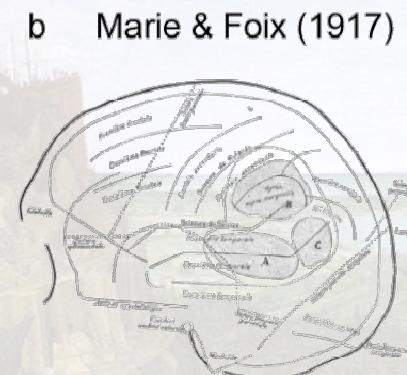
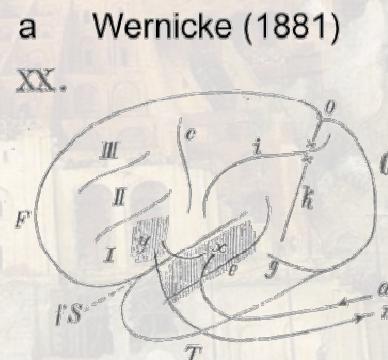
Lesions to Wernicke's area **do not** necessarily result in a Wernicke's aphasia

Wernicke aphasic patients **do not** necessarily have lesions in Wernicke's area

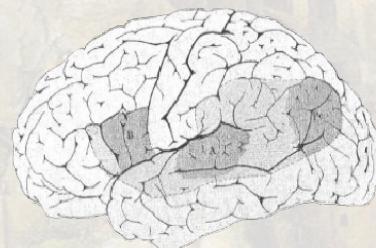
(a) Wernicke defined the speech-receptive region simply as the **whole STG**

(b,c) Later, other neurologists shifted emphasis to **posterior** STG and IPL

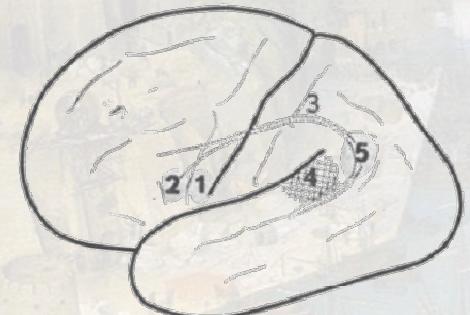
(d) Geschwind depicted Wernicke's area as the '**posterior** language region'



c Dejerine (1921)



d Geschwind (1969)

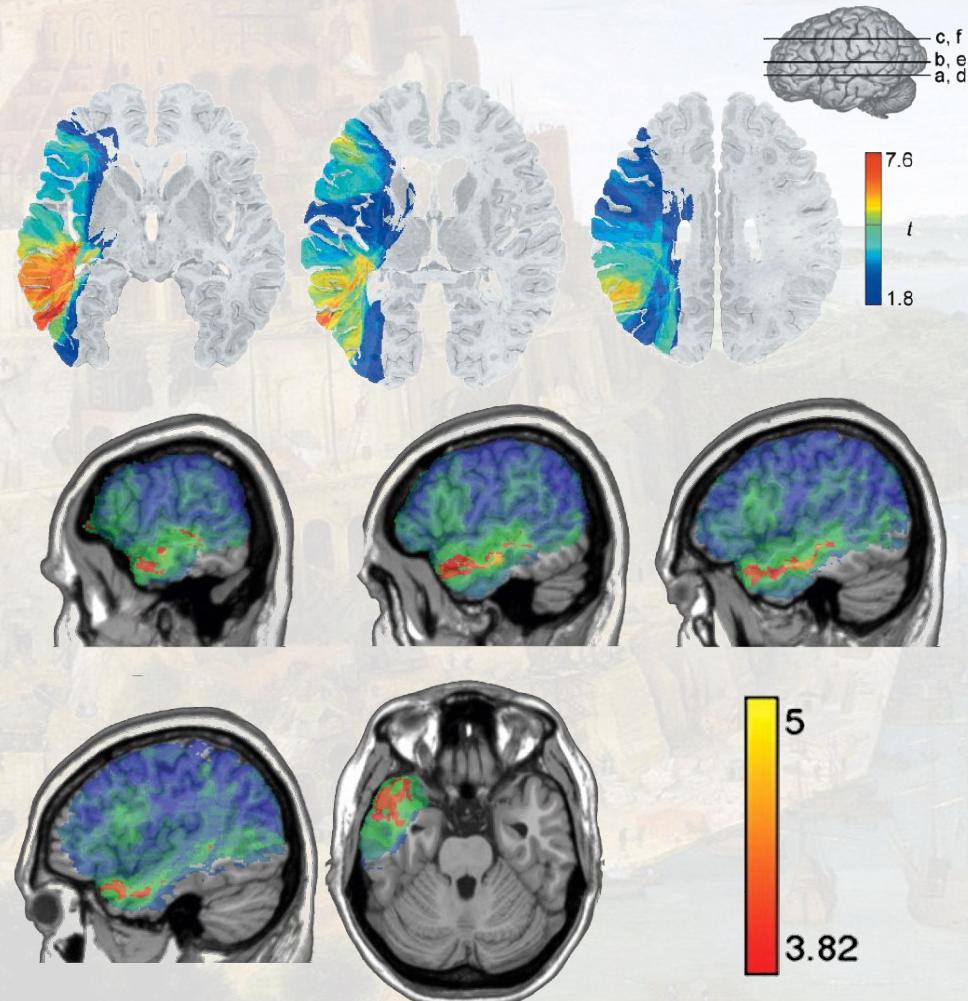


PROBLEMS WITH 'WERNICKE'S AREA'

Top: Voxel-based lesion-symptom mapping on 101 aphasic stroke patients again: Injury to the **middle temporal gyrus produced the largest effect on measures of auditory comprehension**

Bottom: Another VBLS Mapping study: Correlation between semantic errors in naming and lesion data factoring out the non-verbal semantic tests resulted in **anterior temporal regions** significantly correlated with deficits in accessing word level information.

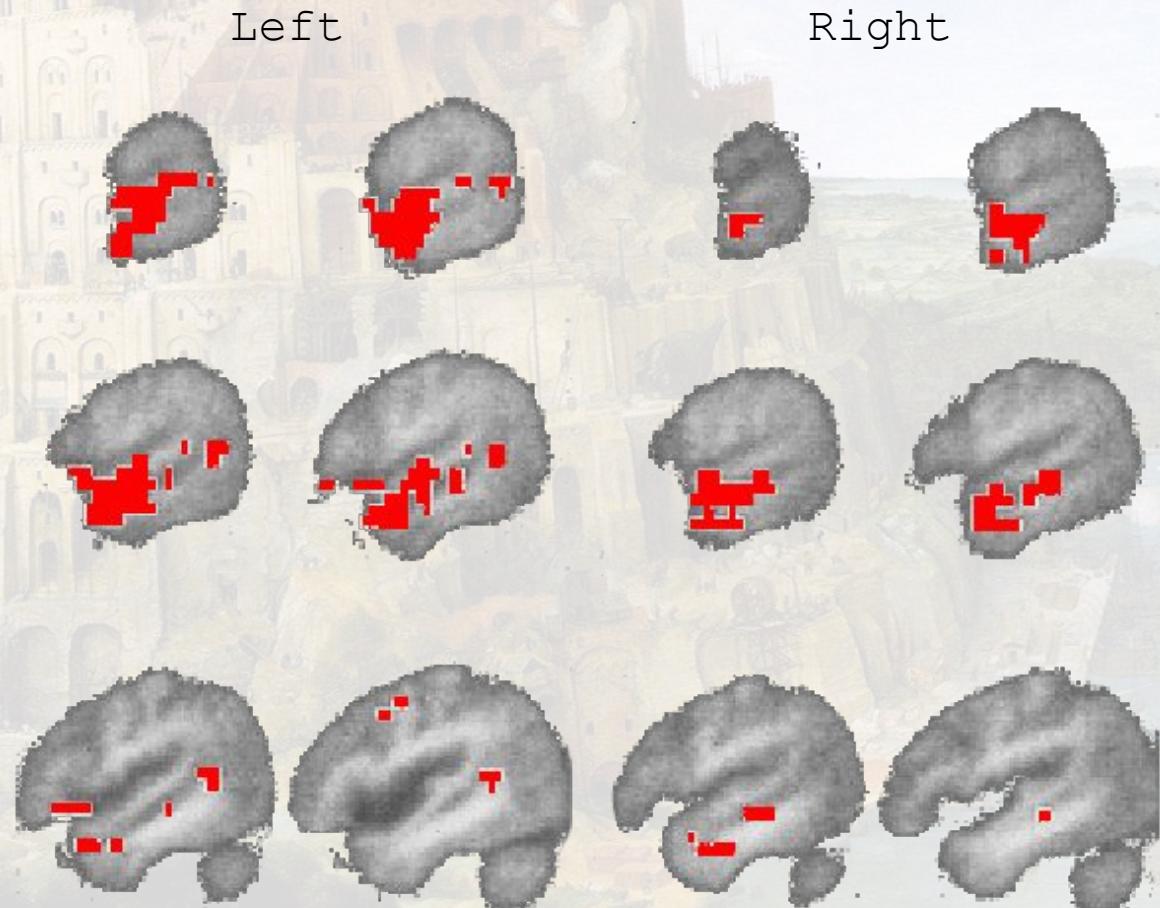
Results '**cast doubt on the classical linkage of semantic error production to lesions in and around Wernicke's area**'



PROBLEMS WITH 'WERNICKE'S AREA'

FMRI: Greater activation for sentences than environmental sounds.

The biggest site of activation is bilateral **anterior temporal lobe**



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

No clear relationship between Broca's Area and speech **production**

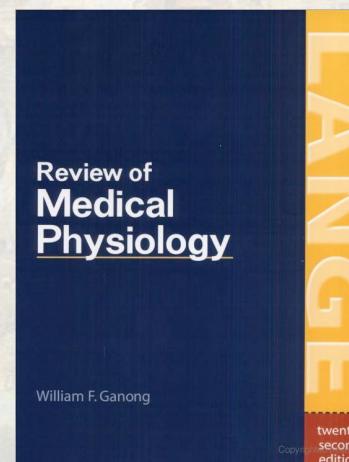
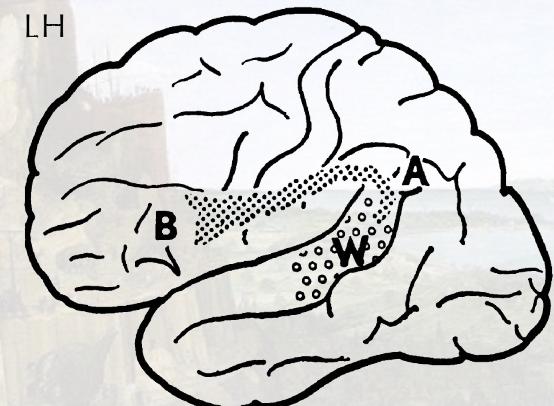
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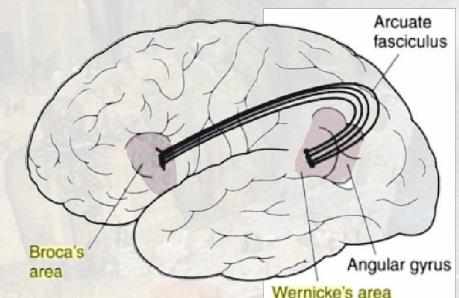


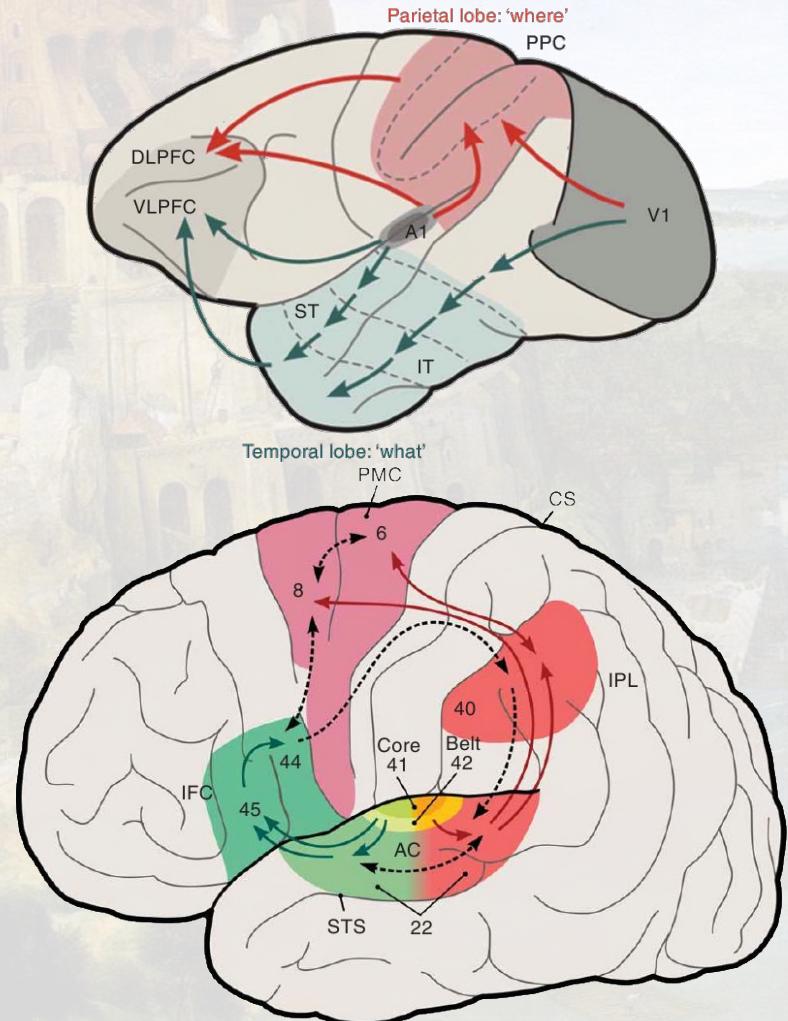
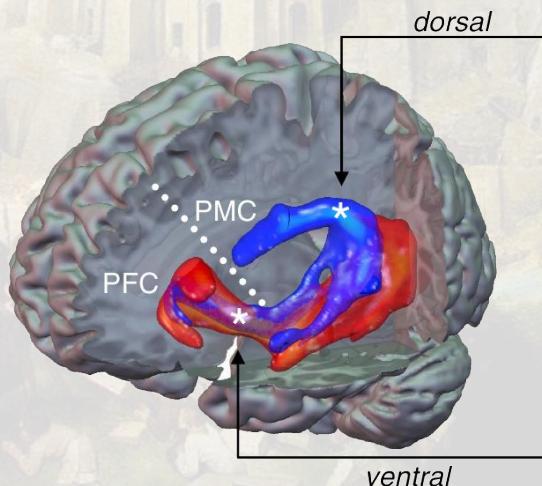
Figure 16-6. Location of some of the areas that in the categorical hemisphere are concerned with language functions.

DUAL PROCESSING FOR NONHUMAN AND HUMAN PRIMATES

Like the two processing streams proposed for vision

Top: For nonhuman primates on anatomical and physiological grounds

Bottom: Antero-ventral (green) and postero-dorsal (red) streams originating from the auditory belt



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

No clear relationship between Broca's Area and speech **production**

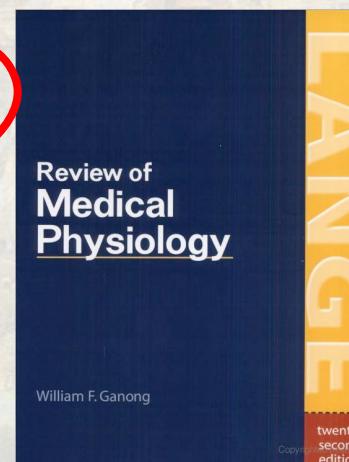
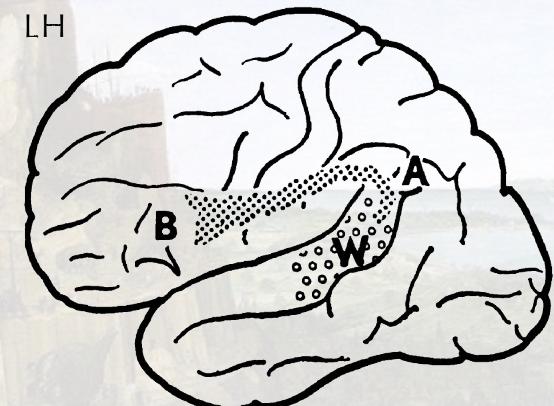
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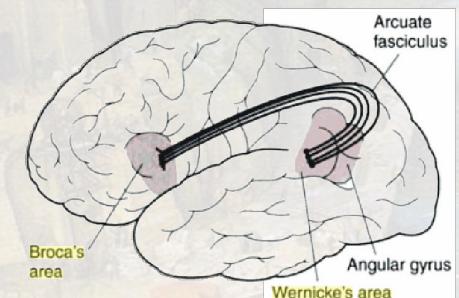


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A LARGE ROLE FOR THE RIGHT HEMISPHERE IN LANGUAGE

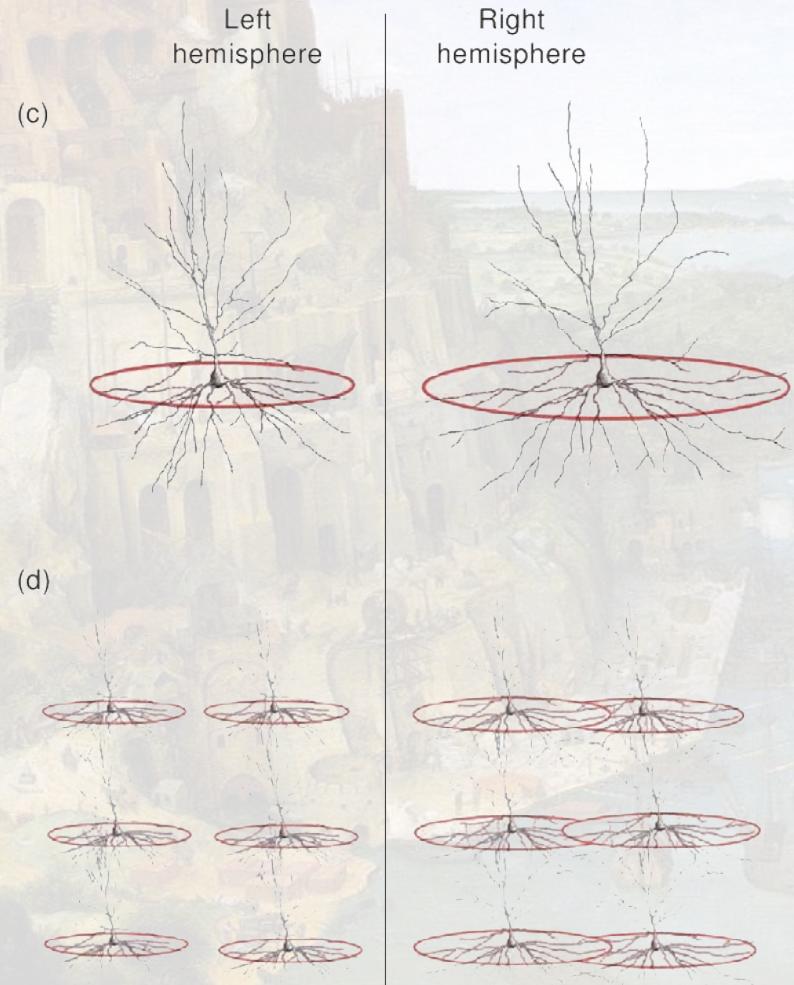
As language **gets more complex**, there is increasing involvement -

**Anterior temporal regions
Right hemisphere (RH)**

Neuroimaging: RH activity > LH -

- Comprehending metaphors
- Getting jokes
- Deriving themes & drawing inferences
- Generating best endings to sentences
- Mentally repairing grammatical errors
- Detecting story inconsistencies
- Determining narrative event sequences

Proposed to correspond to neuronal differences b/n hemispheres



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

No clear relationship between Broca's Area and speech **production**

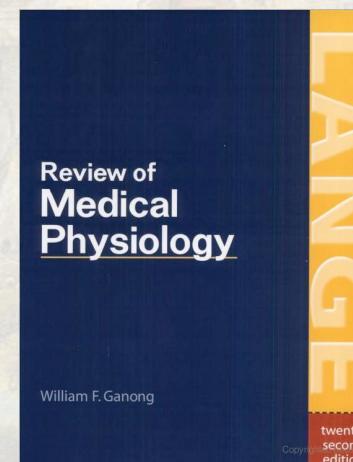
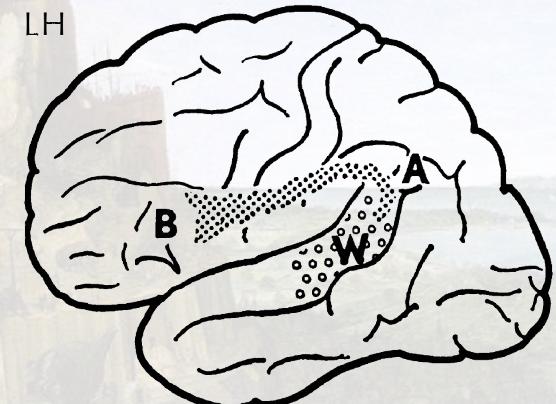
No clear relationship between Wernicke's Area and **language comprehension**

At least **two networks** for language comprehension

Language is not so **left lateralized**

Words are distributed throughout the **whole brain**

Because **language is complex**, passive and bottom-up models do not work



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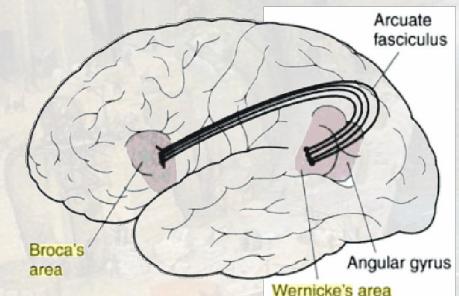


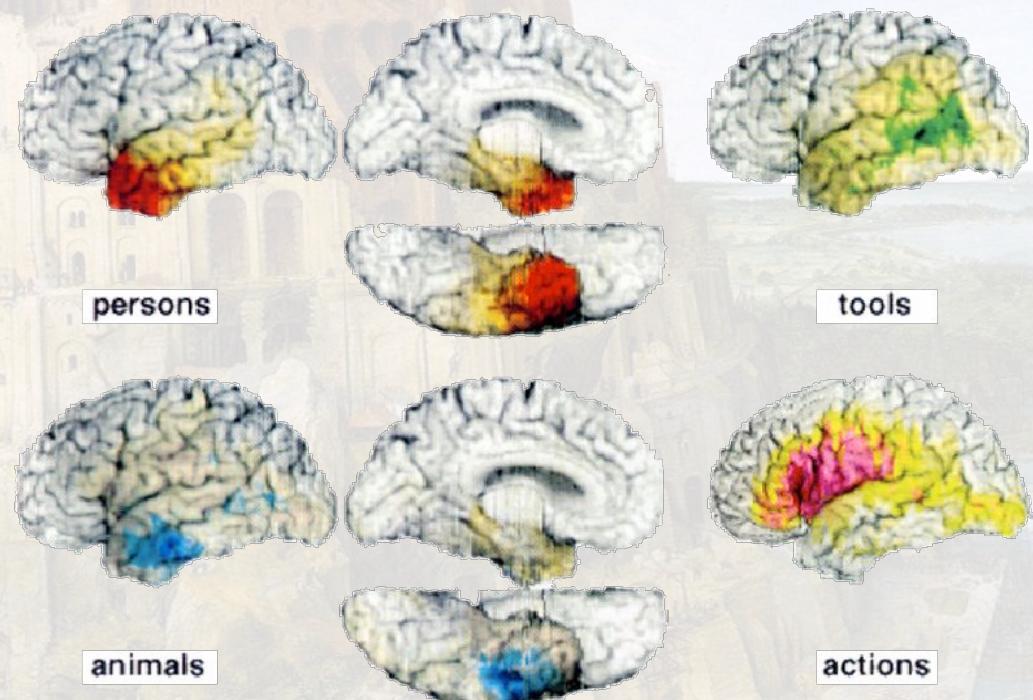
Figure 16-6. Location of some of the areas that in the categorical hemisphere are concerned with language functions.

words are everywhere in the brain

Words represented, in part, by distributed networks that **parallel the organization of sensory and motor systems**

fMRI: Generating the **name of an action activates motion perception areas**

fMRI: Generating a **color word activates color perception areas** (Martin, et al. 1995)



words are everywhere in the brain

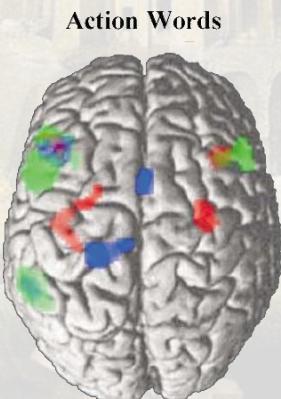
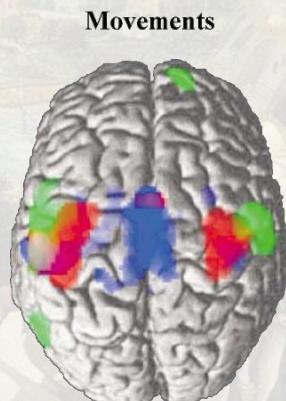
Action word somatotopy:

Read action words referring to **face** = face motor areas

Read action words referring to **hand** = hand/arm motor areas

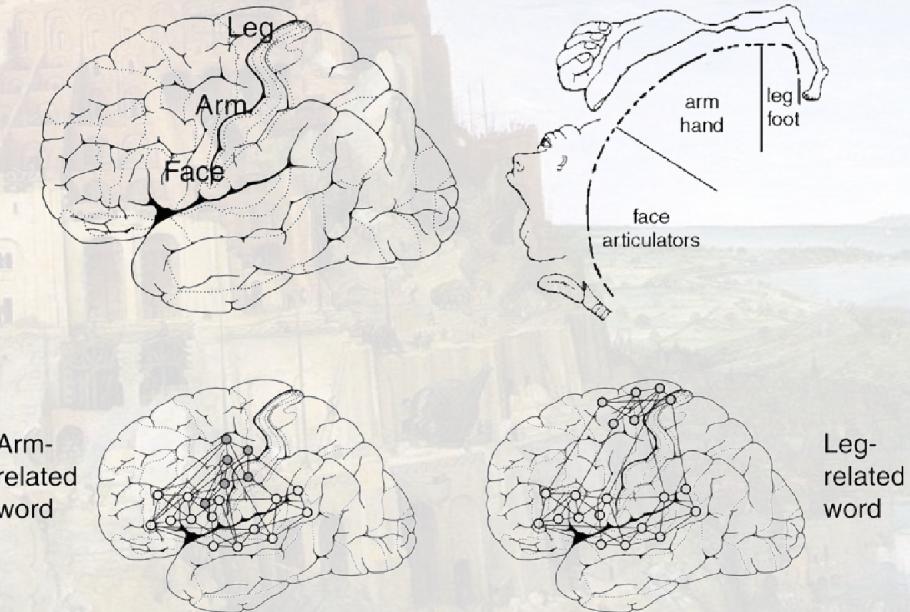
Read action words referring to **foot** = foot motor areas

Rules out a unified 'meaning center'



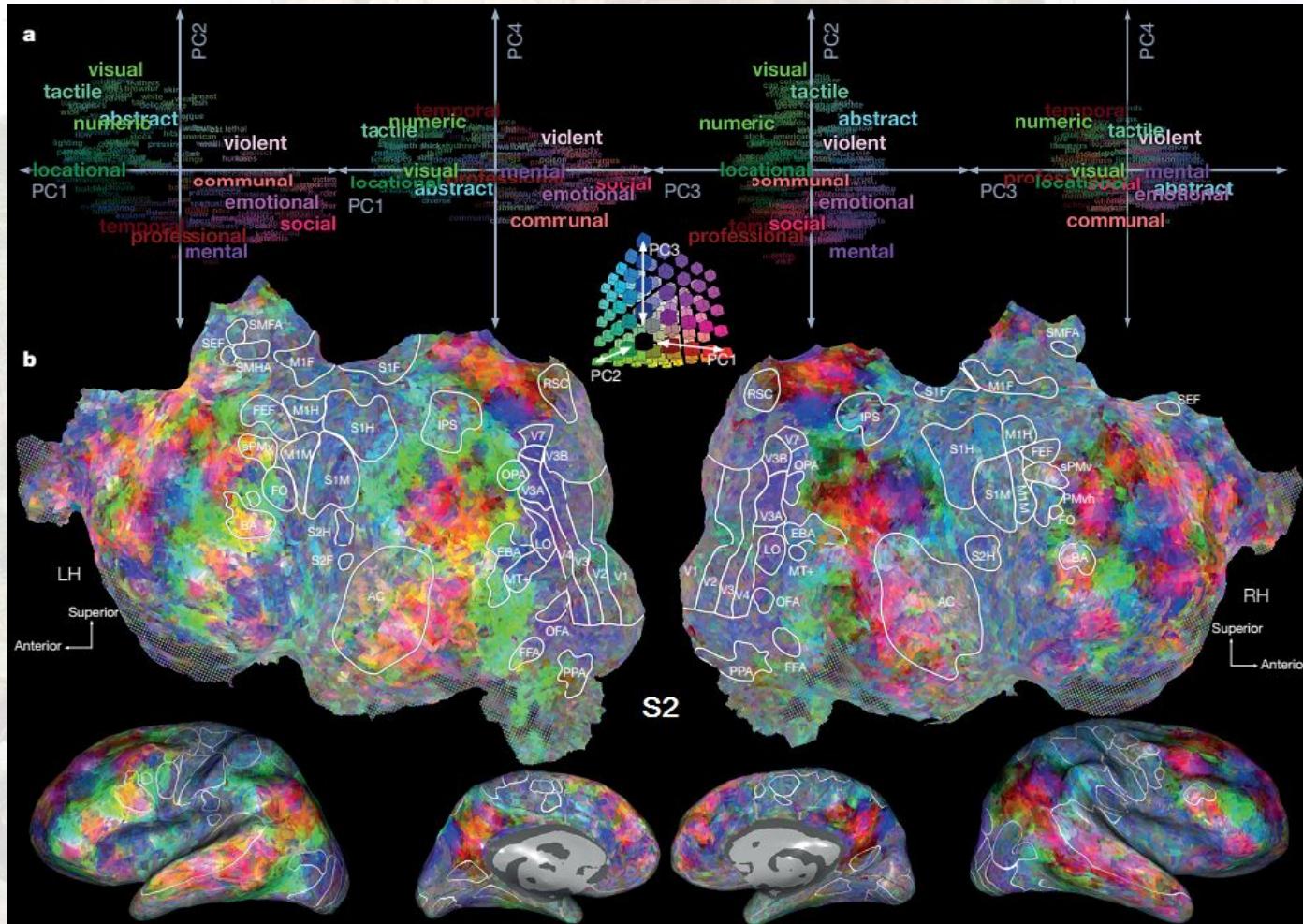
Blue: Foot movements
Red: Finger movements
Green: Tongue movements

Blue: Leg words
Red: Arm words
Green: Face words



words are everywhere in the brain

Rules out a unified 'meaning center'



PROBLEMS WITH THE WERNICKE - GESCHWIND MODEL

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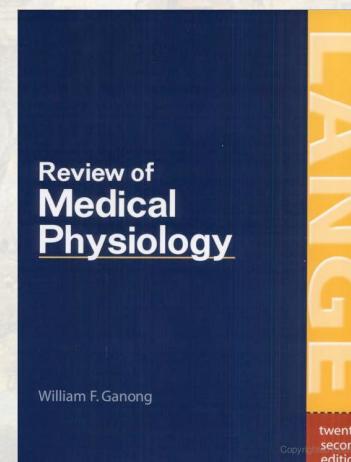
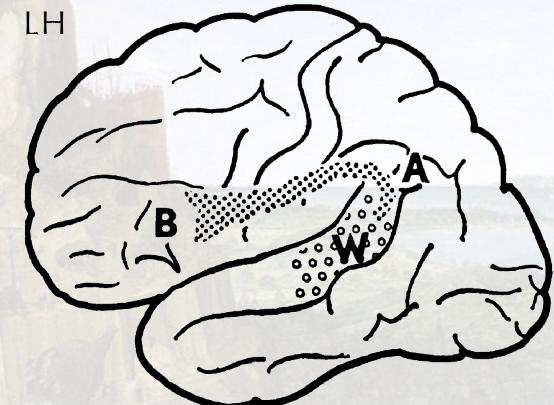
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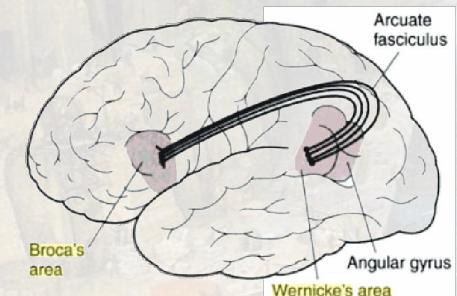
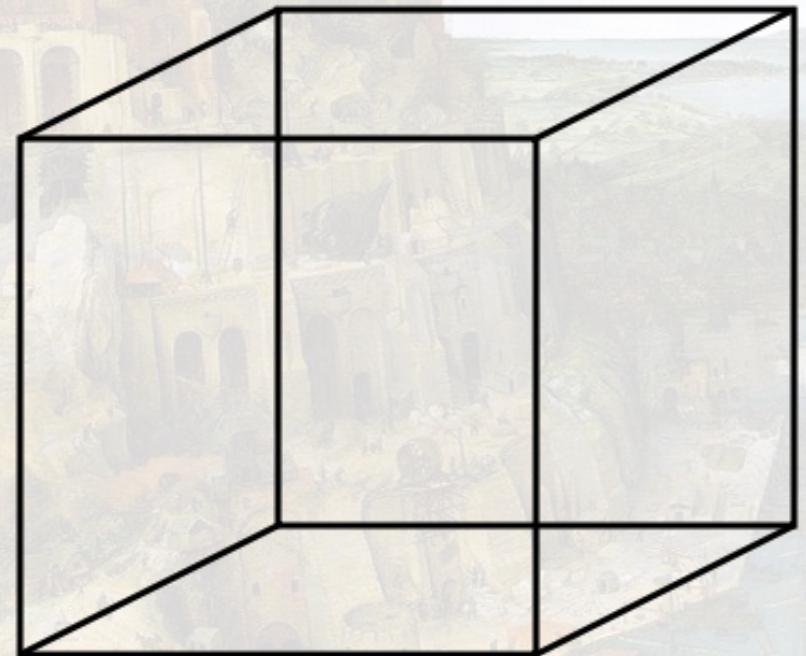


Figure 16-6. Location of some of the areas that in the categorical hemisphere are concerned with language functions.

PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis -

Sound: Speech Perception is a grand illusion?



PROBLEMS FOR UNDERSTANDING LANGUAGE

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Sound: Speech Perception is a grand illusion?

- The **Segmentation Problem:**

- “I owe you a yoyo.”
- Find the 5 words and six syllables.



PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis:

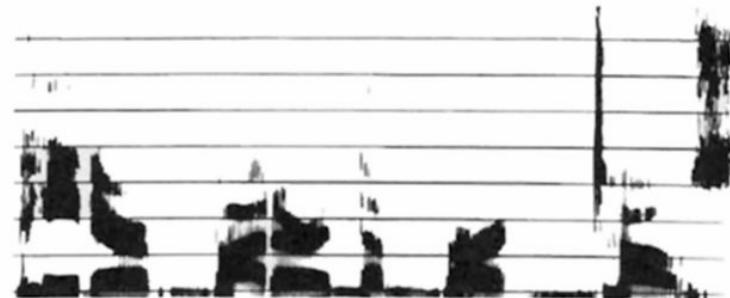
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- “Peter buttered the burnt toast.”
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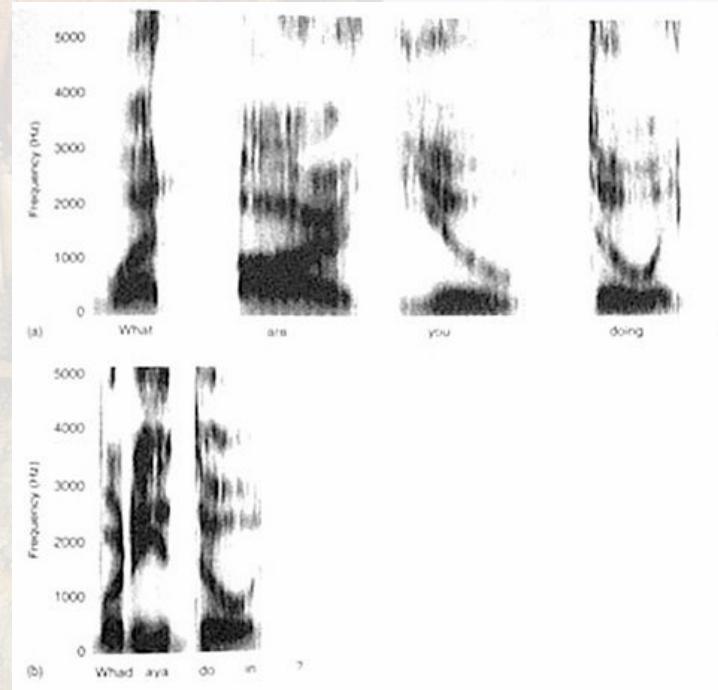
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- **Speaking Rate:**

- “What are you doing?” Pronounced slowly and distinctly (a) and conversationally (b).

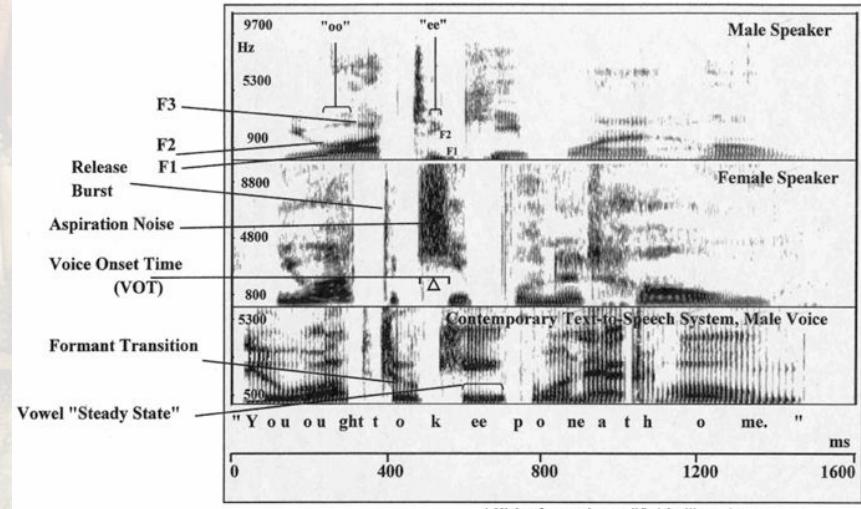


PROBLEMS FOR UNDERSTANDING LANGUAGE

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 - "Peter buttered the burnt toast."
 - Find the five "t"s.
- **Speaking Rate:**
 - "What are you doing?" Pronounced slowly and distinctly (a) and conversationally (b).
- **Talker differences**



PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis:

Sound

Lexical

- "The bat was found in the attic."
- Here "bat" is homonymous; An instrument used in sport or a flying mammal.
- Polysemy even more troublesome, e.g., ~84% of relatively frequent words have more than one sense and 37% have more than five senses.
- Consider "door" as a physical object in "The door fell off its hinges" or as an aperture in "The child ran through the door".



PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis:

Sound

Lexical

Syntactic

- "Intelligent students and faculty members presented papers at the conference"
- Intelligent could modify students or both students and faculty members.



PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis:

Sound

Lexical

Syntactic

Lexical and Syntactic

- "Mary made her dress correctly"
- Can be read as Mary having sewn her dress to the right specifications or Mary having made her daughter dress appropriately for an occasion.



PROBLEMS FOR UNDERSTANDING LANGUAGE

Ambiguity of the units of analysis:

Sound

Lexical

Syntactic

Lexical and Syntactic

How does the brain get around these problems?





GETTING Around THESE PROBLEMS FROM THE TOP-DOWN



Speech-associated mouth movements improve speech perception.

(e.g., Sumby & Pollack, 1954; Reisberg, McLean, & Goldfield, 1987)

GETTING Around THESE PROBLEMS FROM THE TOP-DOWN



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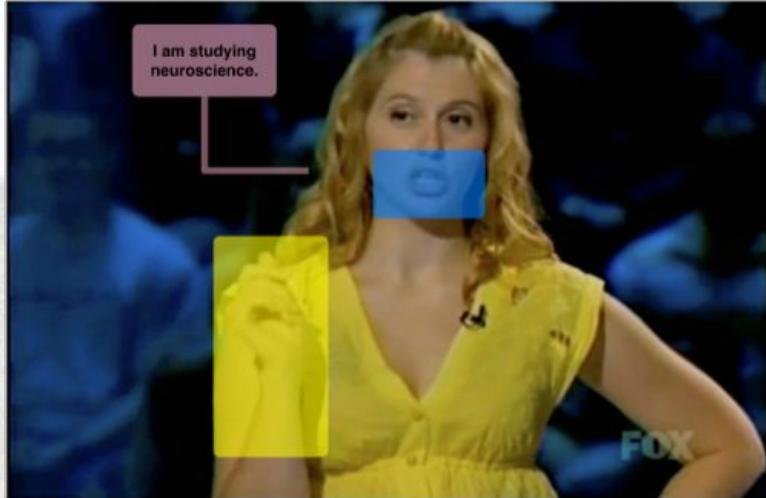
(e.g., Sumby & Pollack, 1954; Reisberg, McLean, & Goldfield, 1987)



Co-speech gestures improve language comprehension.

(e.g., McNeill, Cassell, & McCullough, 1994; Singer & Goldin-Meadow, 2005)

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Preceding discourse content improves language comprehension.

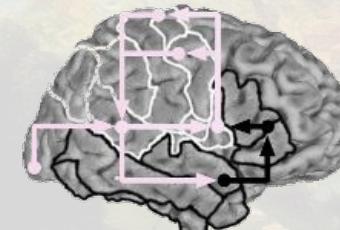
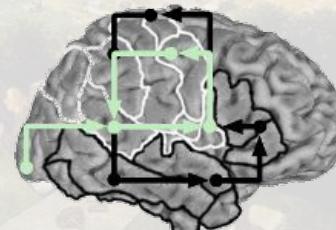
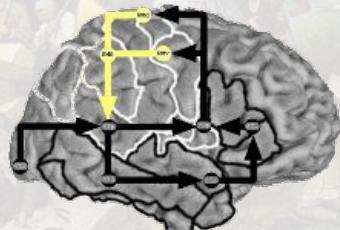
(e.g., Kutas & Hillyard, 1984; Marslen-Wilson & Welsh, 1978; Rubin & Turvey, 1976; Warren, 1970)

GETTING Around THESE PROBLEMS FROM THE TOP-DOWN

Speech perception is (most often) an active or top-down process (Skipper et al., 2005, 2006, 2007, 2009, 2014, 2015, 2017).

That is, using contextual information, listener's brains form hypotheses about the linguistic categories that could account for a particular stretch of utterance.

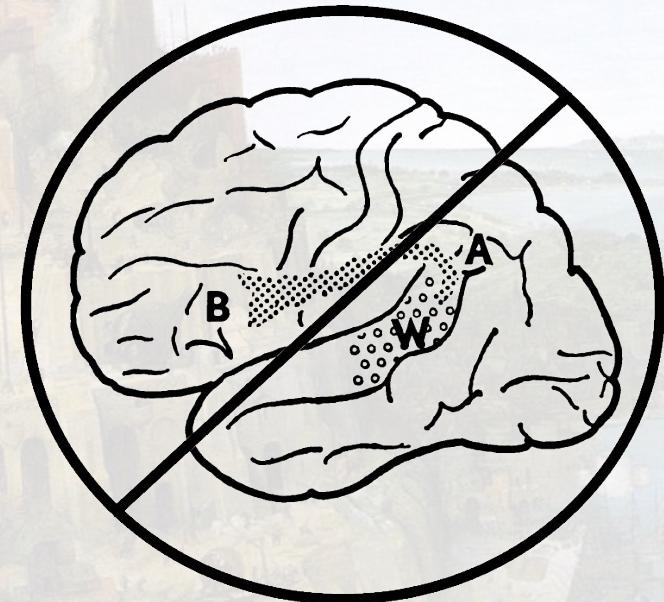
The brain can then predict the sensory consequences of those hypotheses and constrain interpretation of incoming sensory information.



IT IS TIME TO RETIRE THE WERNICKE - GESCHWIND MODEL

"There is **no 'centre of Speech' in the brain** any more than there is a faculty of Speech in the mind. The entire brain, more or less, is at work in a man who uses language.'

William James
The Principles of Psychology, 1890



Little **evidence** for the Wernicke-Geschwind model

Why do we continue to teach this model to everyone? (Momentum? Ease?)

Benefits of teaching a new model include potentially having a **profound impact on**, e.g., recovery from **aphasia** (lowest health related quality of life)?

