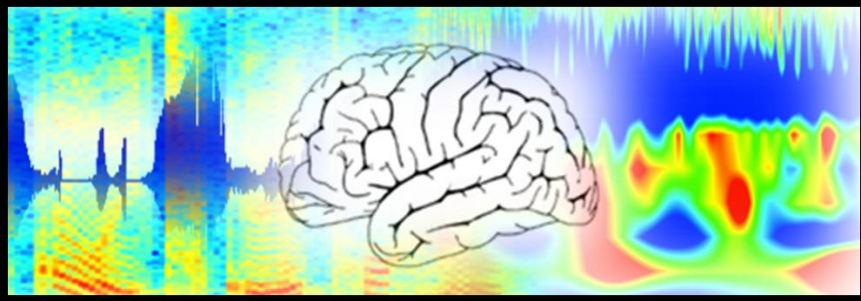
Universität Zürich[UZH]



# The neural signature of (spoken) language

***Conference Hand to Mouth***

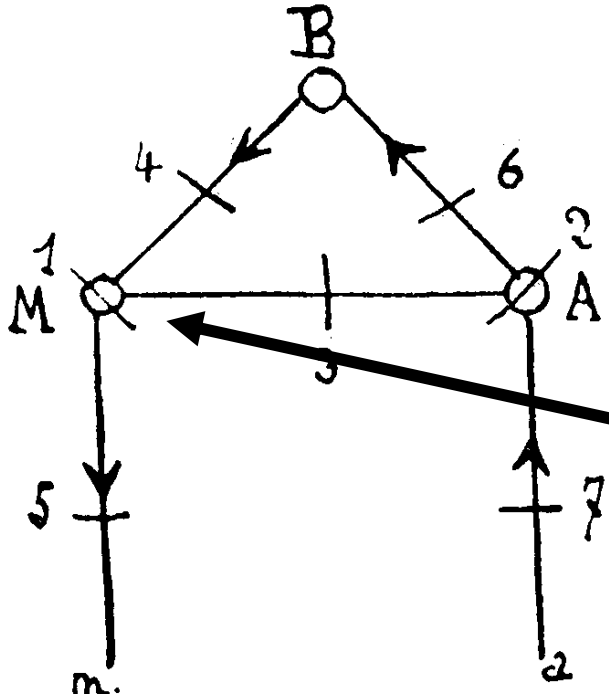
***Zurich 2013***

**Martin Meyer**
**“Neuroplasticity and Learning in the Aging Brain”**
**Psychological Institute**
**University of Zurich**

# Issues

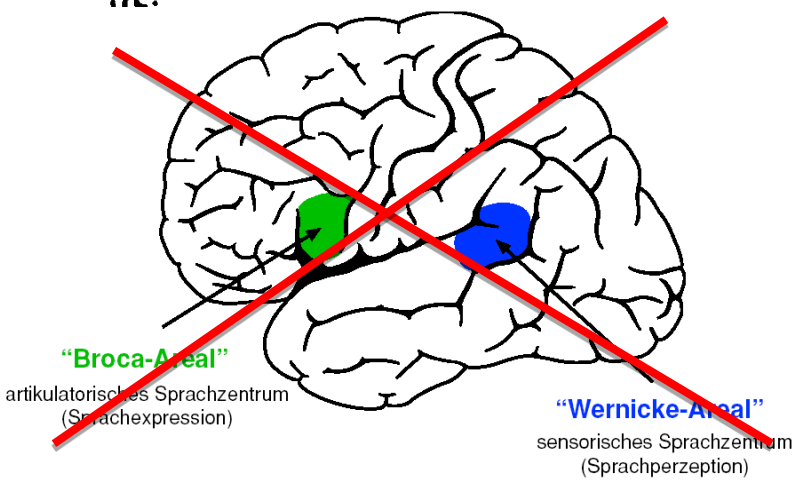
- **Language and the brain – the classical model**
- Performance and modality
- Division of labour between left and right hemisphere
- Current neurolinguistic models
- Conceptual problems

# The Wernicke-Lichtheim Model (1884)




**Wernicke Area**: full word auditory images through which the meaning of words can be accessed

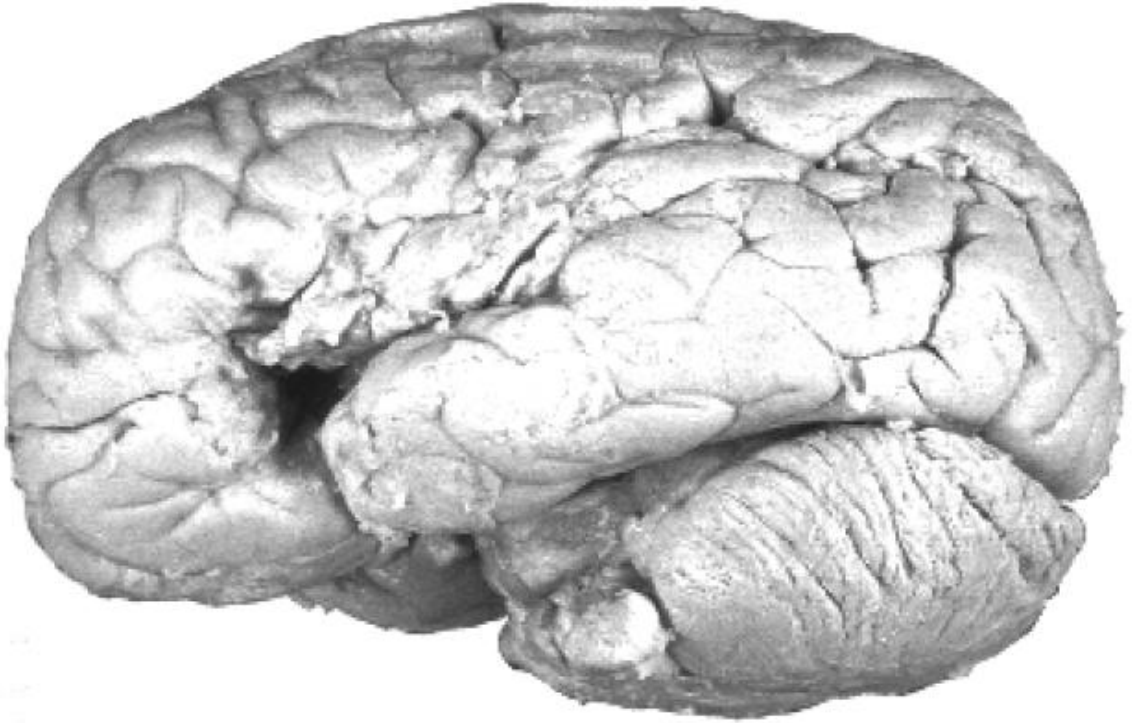
**Broca Area**: motor representation of words to trigger motor output



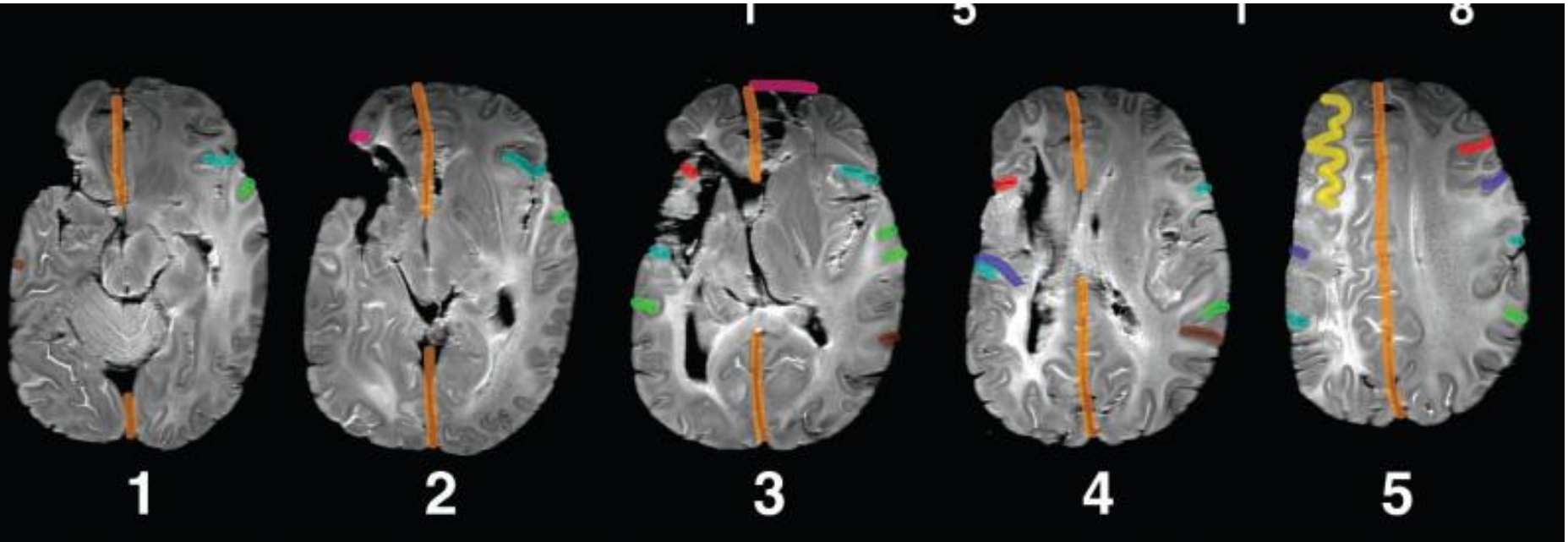

The classical model is
(1) limited to the word-level,
(2) reflects language as performance (repetition, articulation, comprehension)
(3) is anatomically ill-defined
(4) is lesion-based


© 1995

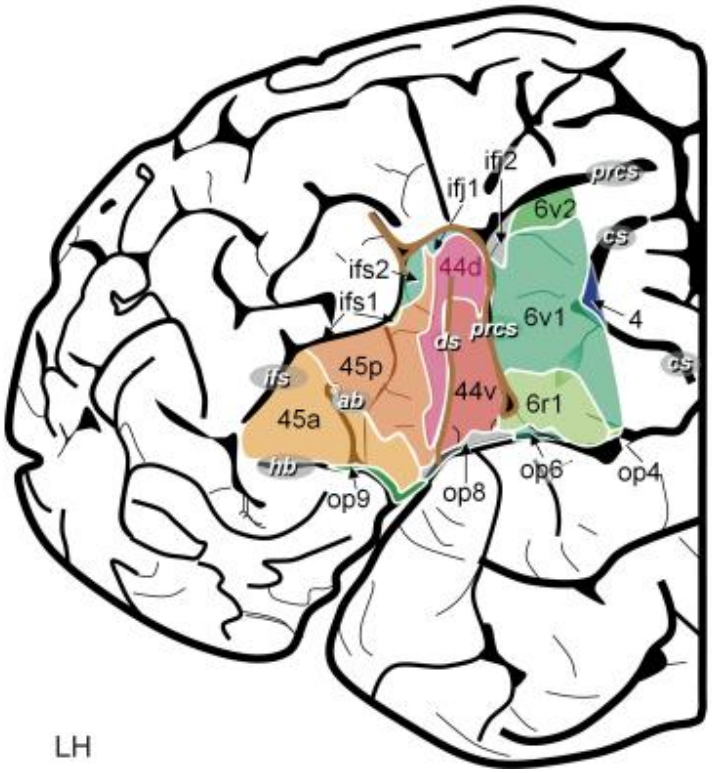
Amunts & Zilles (2006)

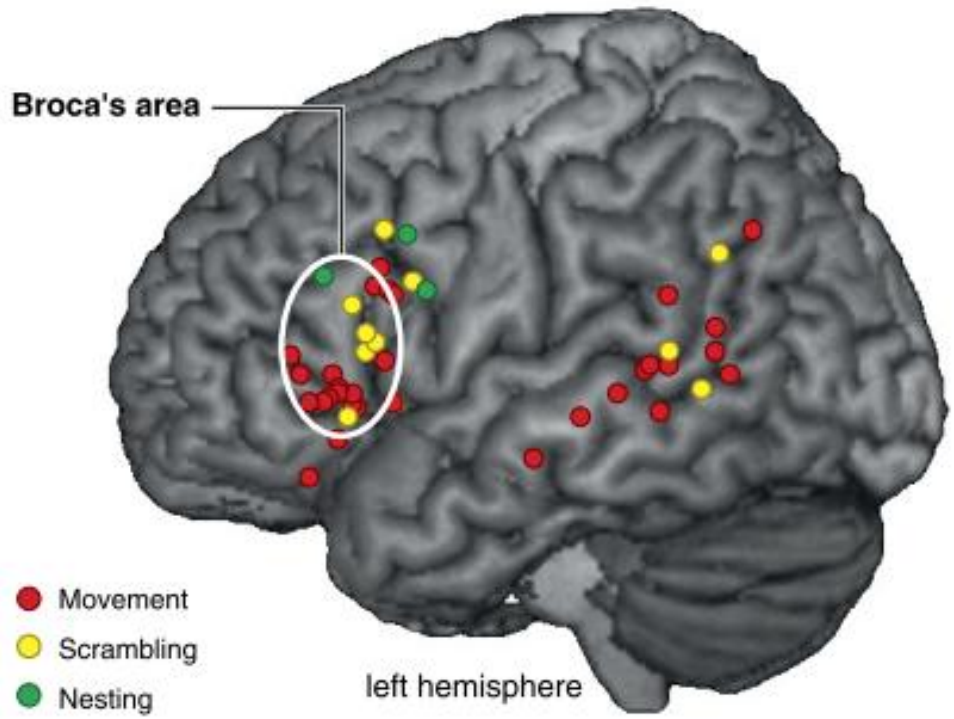


Dronkers et al. 2007

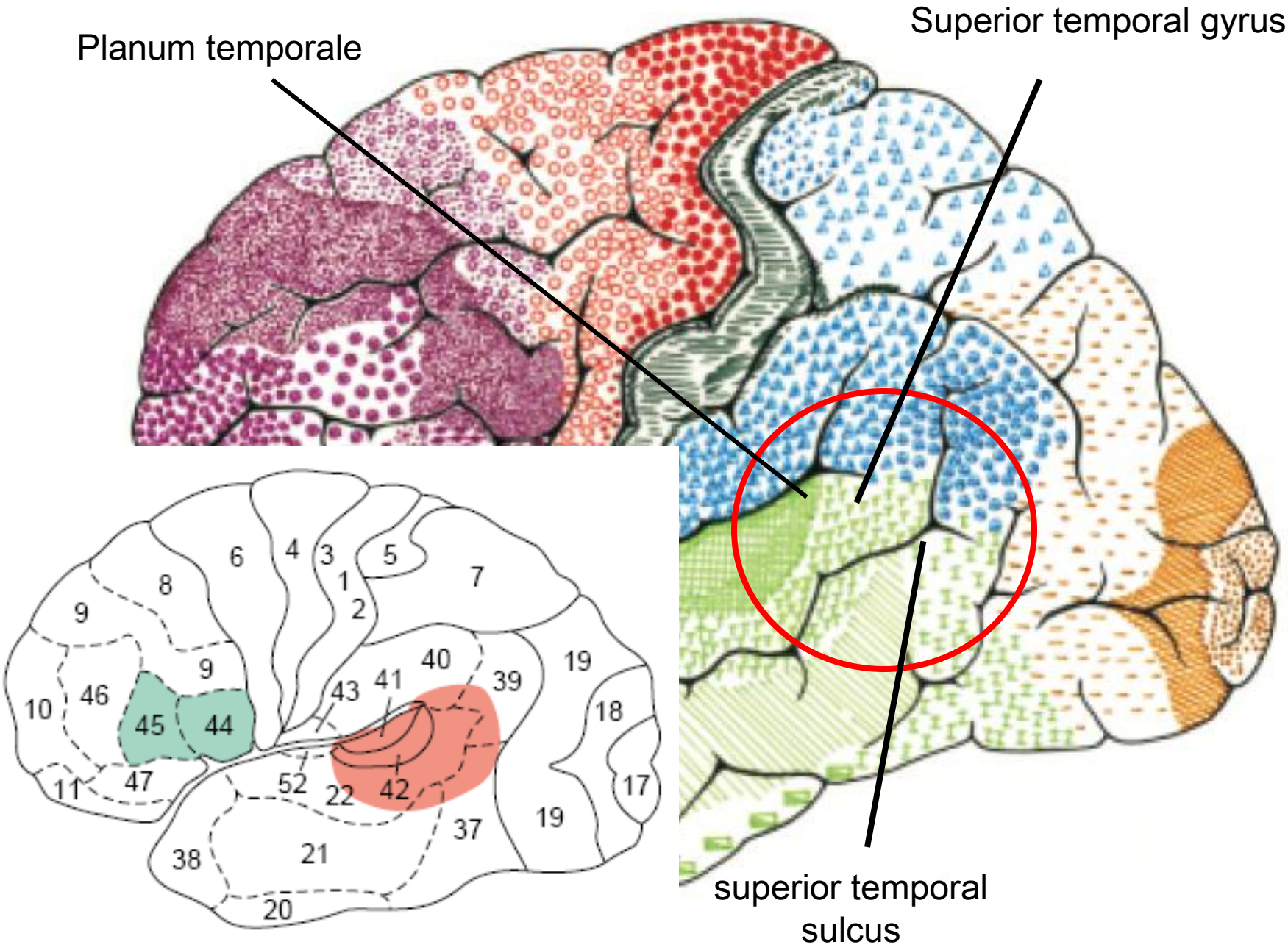


# Broca's region




Friederici (2011), Physiol Rev

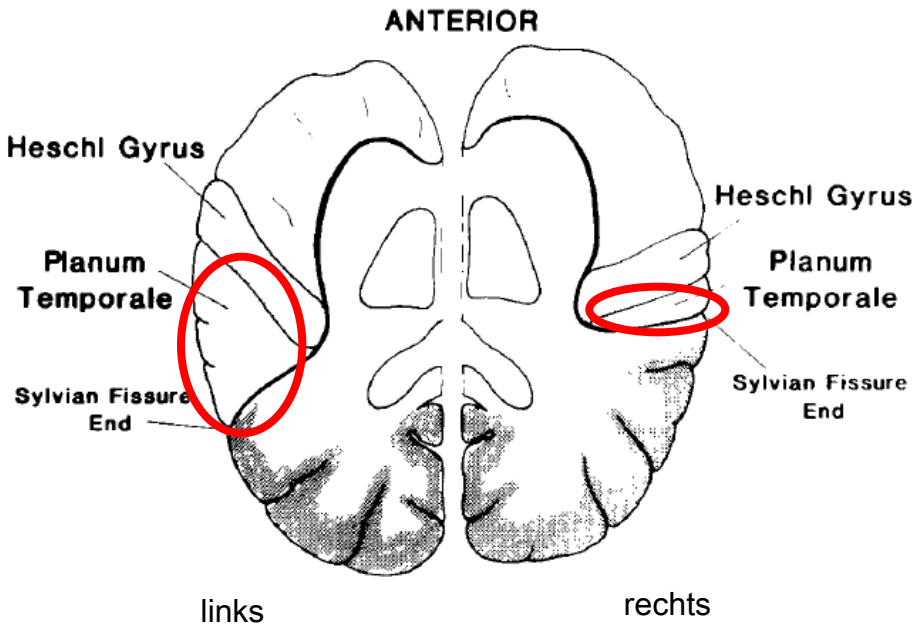


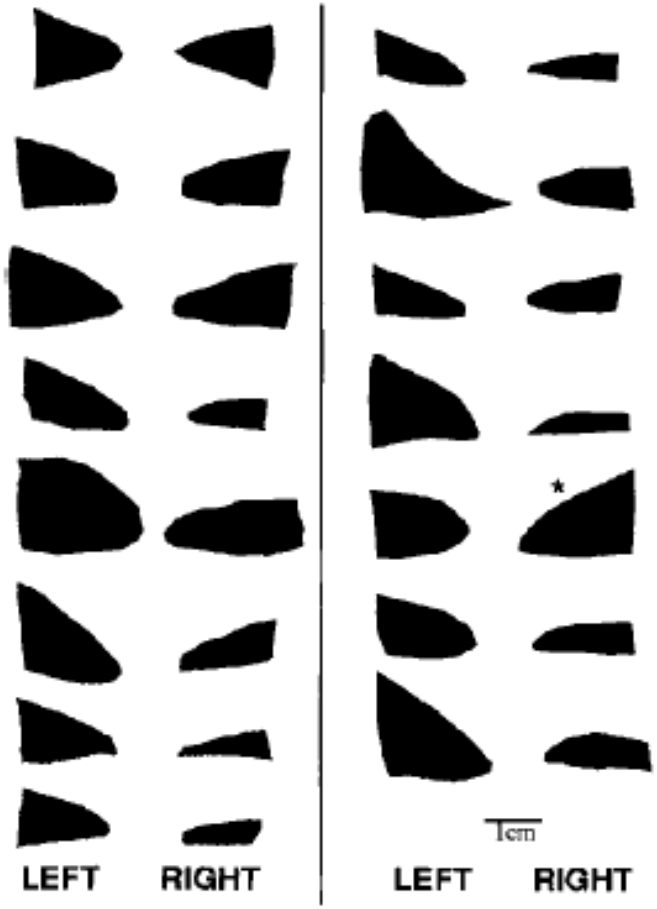

Kaan & Swaab (2002)

Amunts & Zilles (2006)

# Hemispheric asymmetry and perceptual vocalisation

## Planum temporale



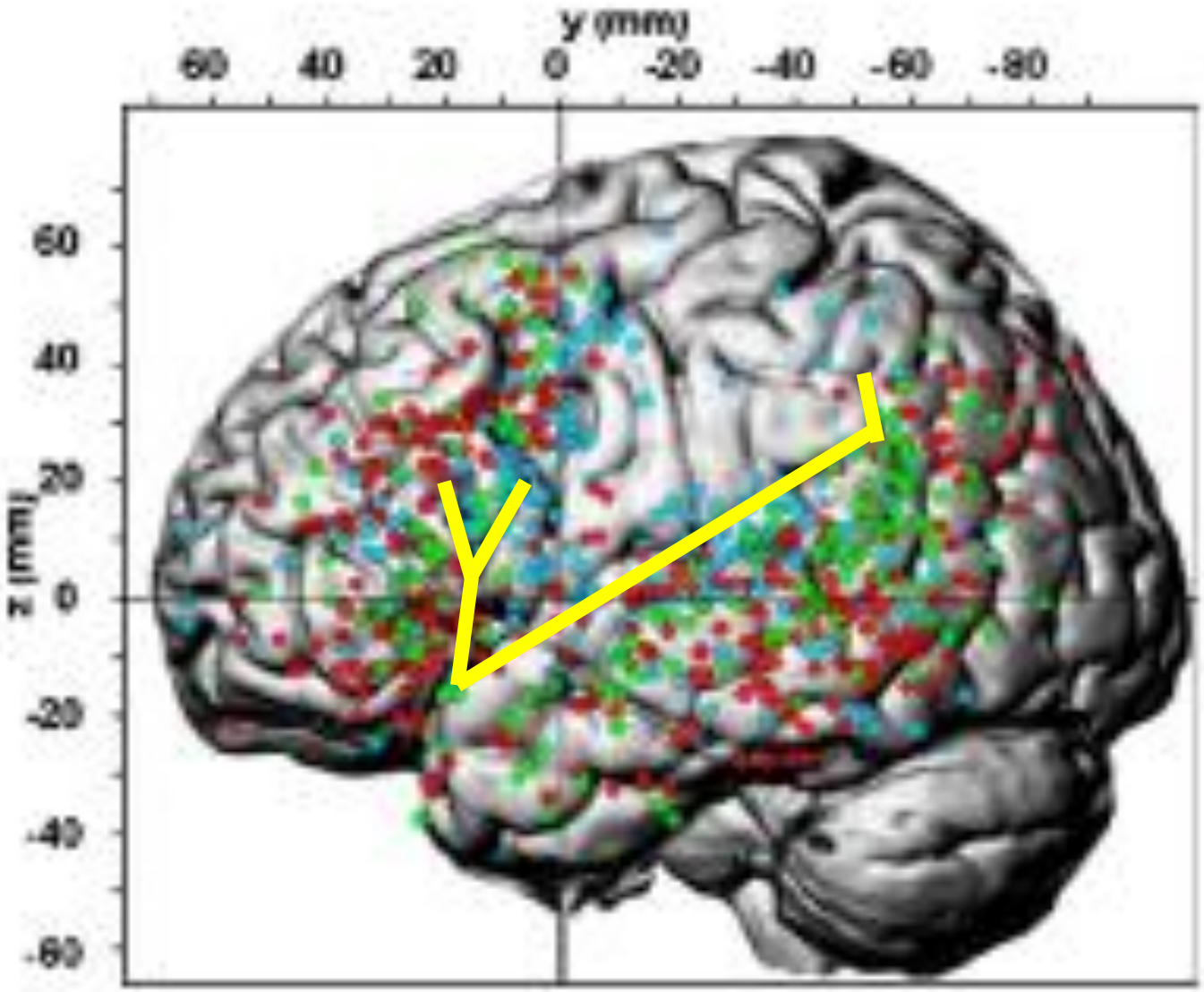

Human

Great apes

Galaburda et al. (1978), Arch Neurol

Gannon et al. (1998), Science

Vigneau et al. (2006), NeuroImage



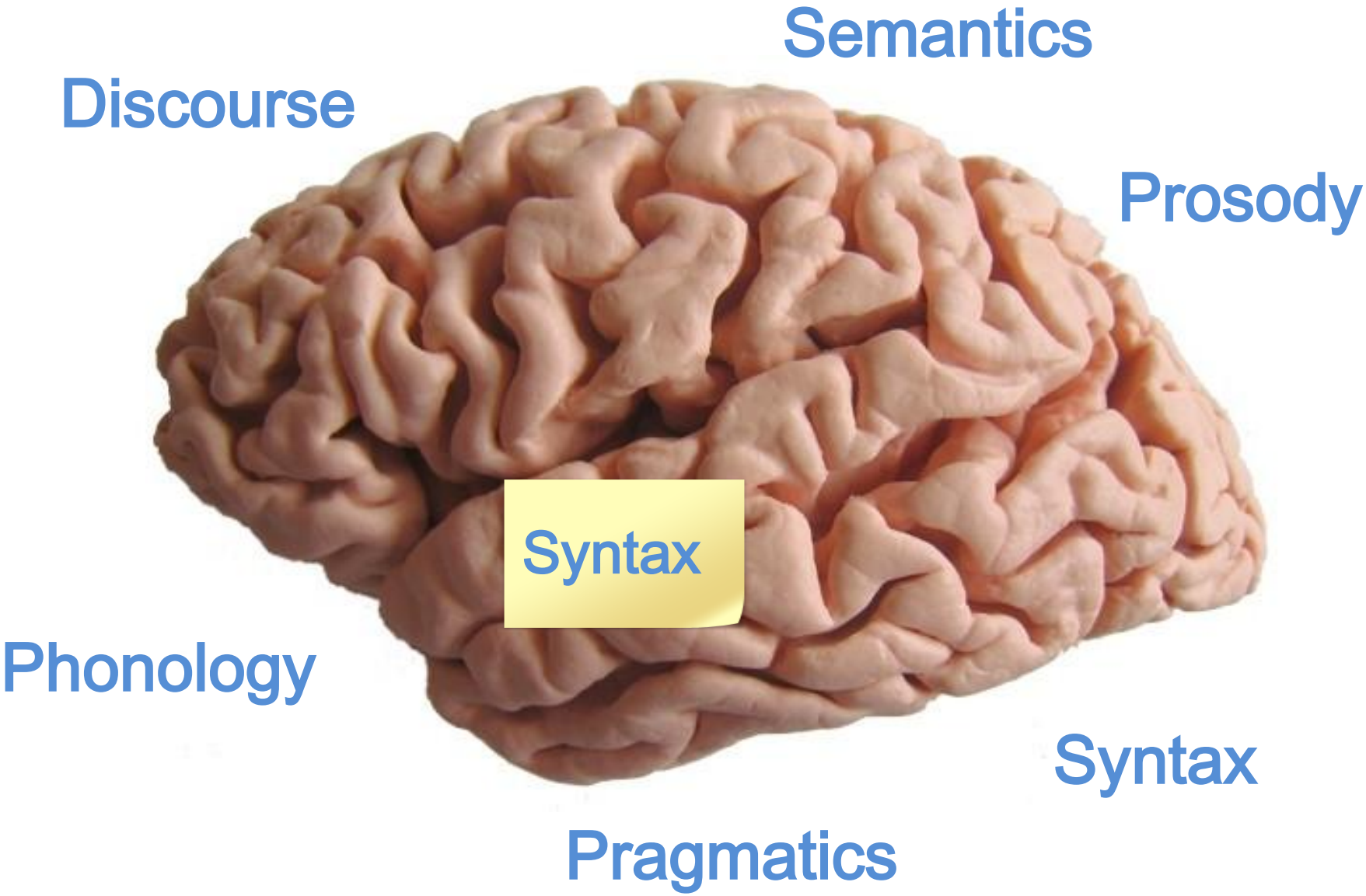

Phonologie

Semantik

Syntax

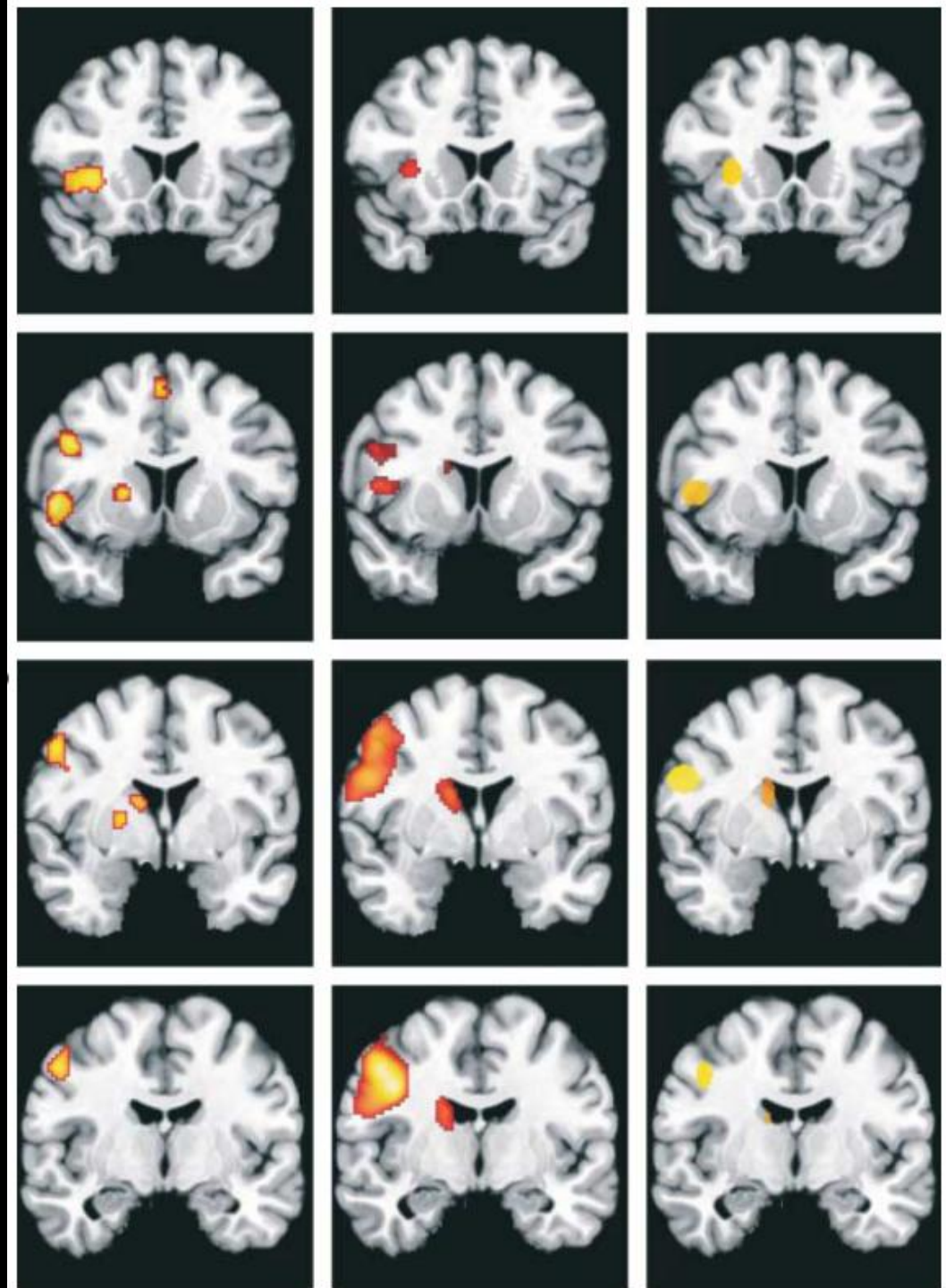
# Sylvian Fissure / Perisylvian Region

# The language of the brain ?



# Issues

- Language and the brain – the classical model
- **Performance and Modality**
- Division of labour between left and right hemisphere
- Current neurolinguistic models
- Conceptual problems



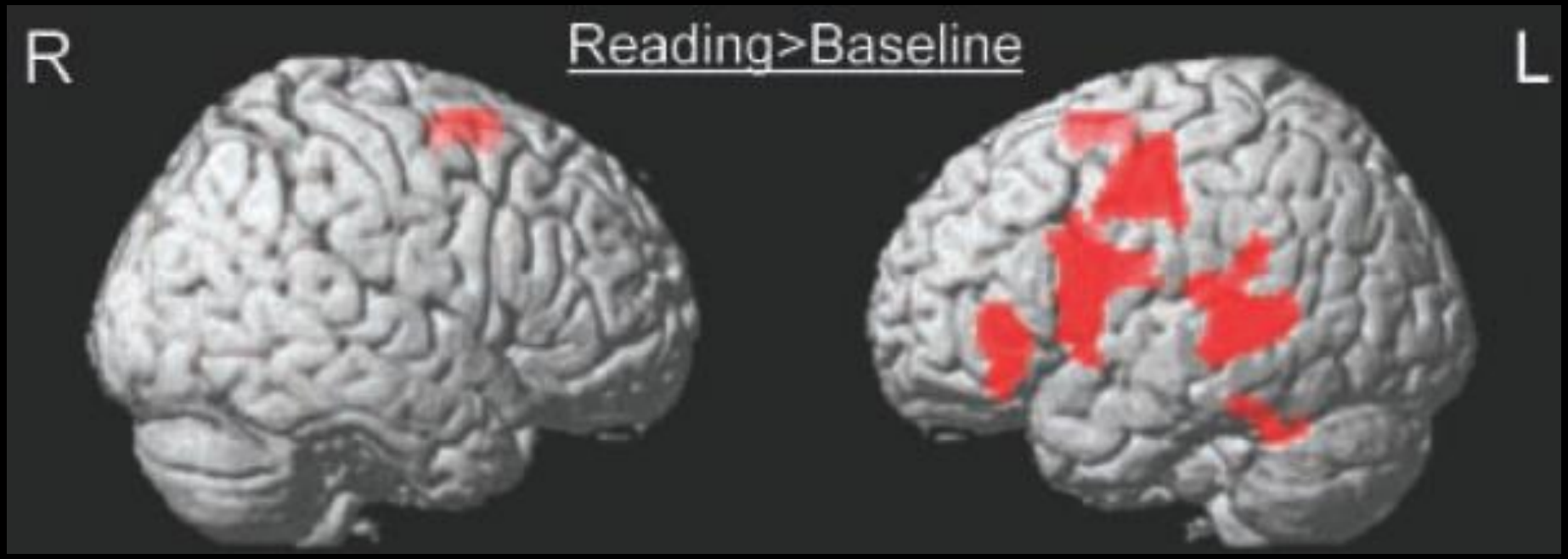
Eickhoff et al. (2009)

Broca's area / insula

Overt
speech production

M1 / basal ganglia

# Adult readers recruit a comprehensive, large-scale, left dominant network (Price et al. 2005)

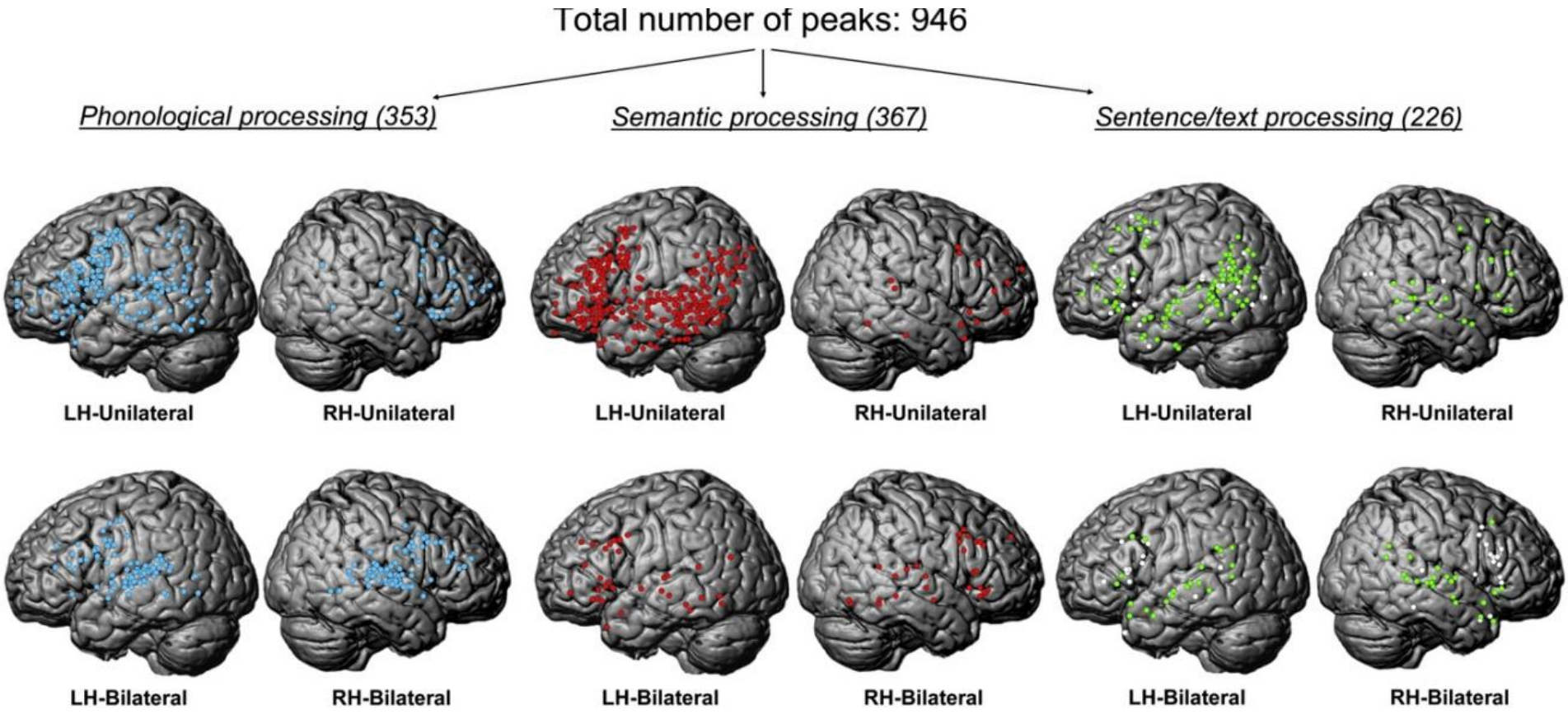



Mechelli et al. (2005)

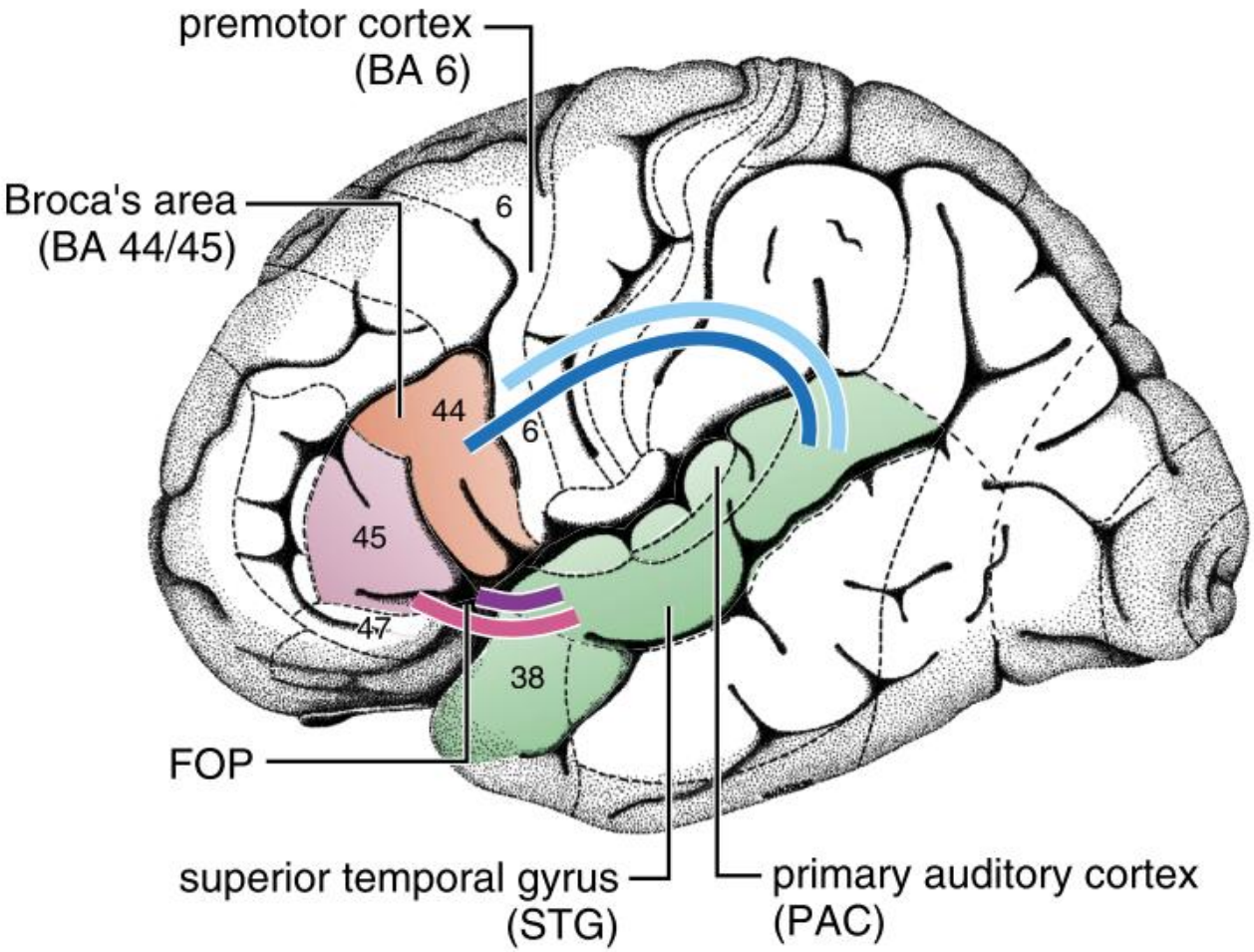
# Issues

- Language and the brain – the classical model
- Performance and Modality
- **Division of labour between left and right hemisphere**
- Current neurolinguistic models
- Conceptual problems

# Meta-analysis across 128 studies




Vigneau et al. 2011, NeuroImage




**Dorsal Pathway I**

pSTG to premotor cortex via AF/SLF

**Ventral Pathway I**

STG to BA 45 via EFCS

**Dorsal Pathway II**

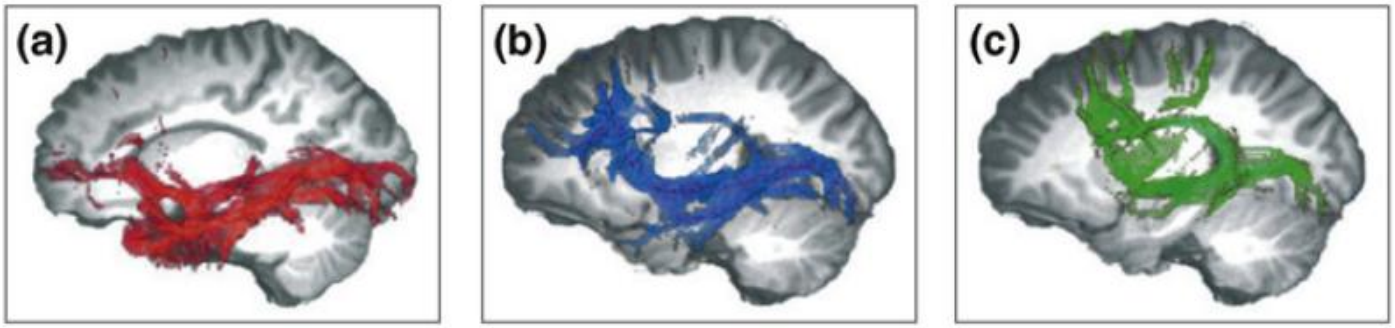
pSTG to BA 44 via AF/SLF

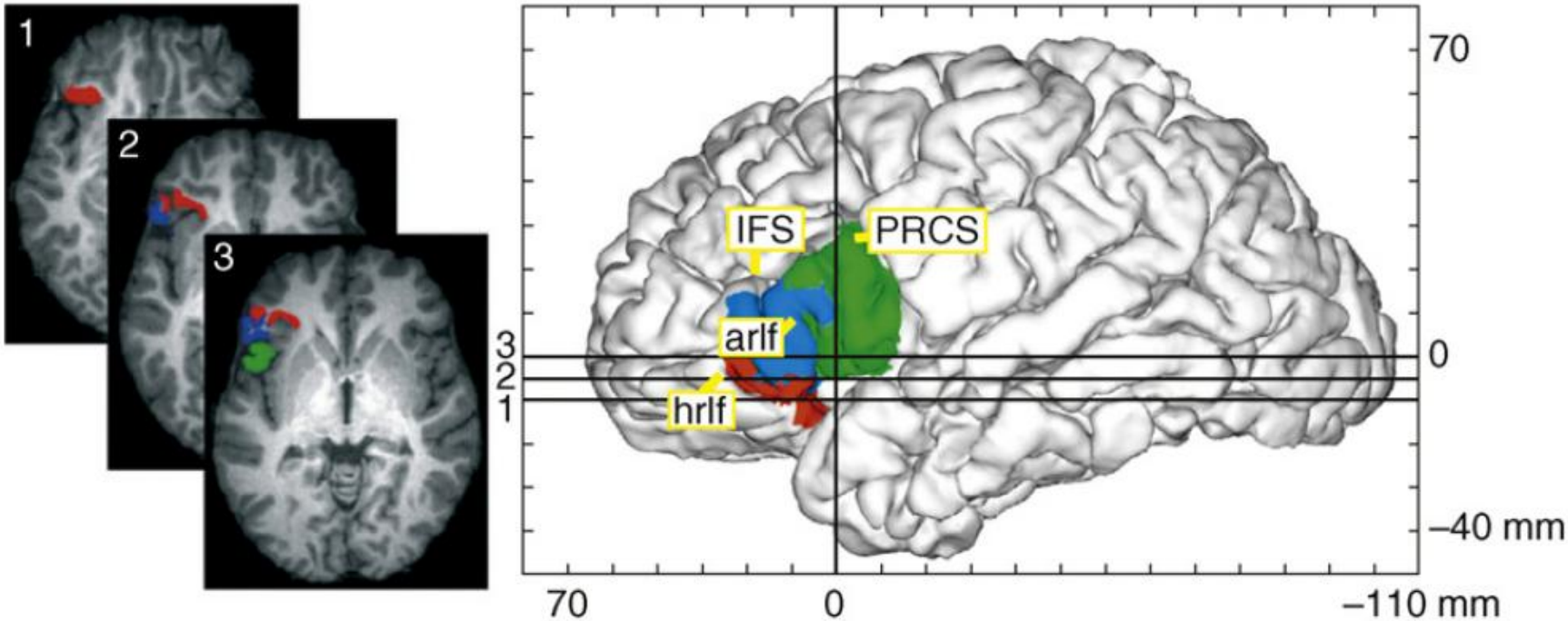
**Ventral Pathway II**

antSTG to FOP via UF

Friederici (2011), Physiol Rev

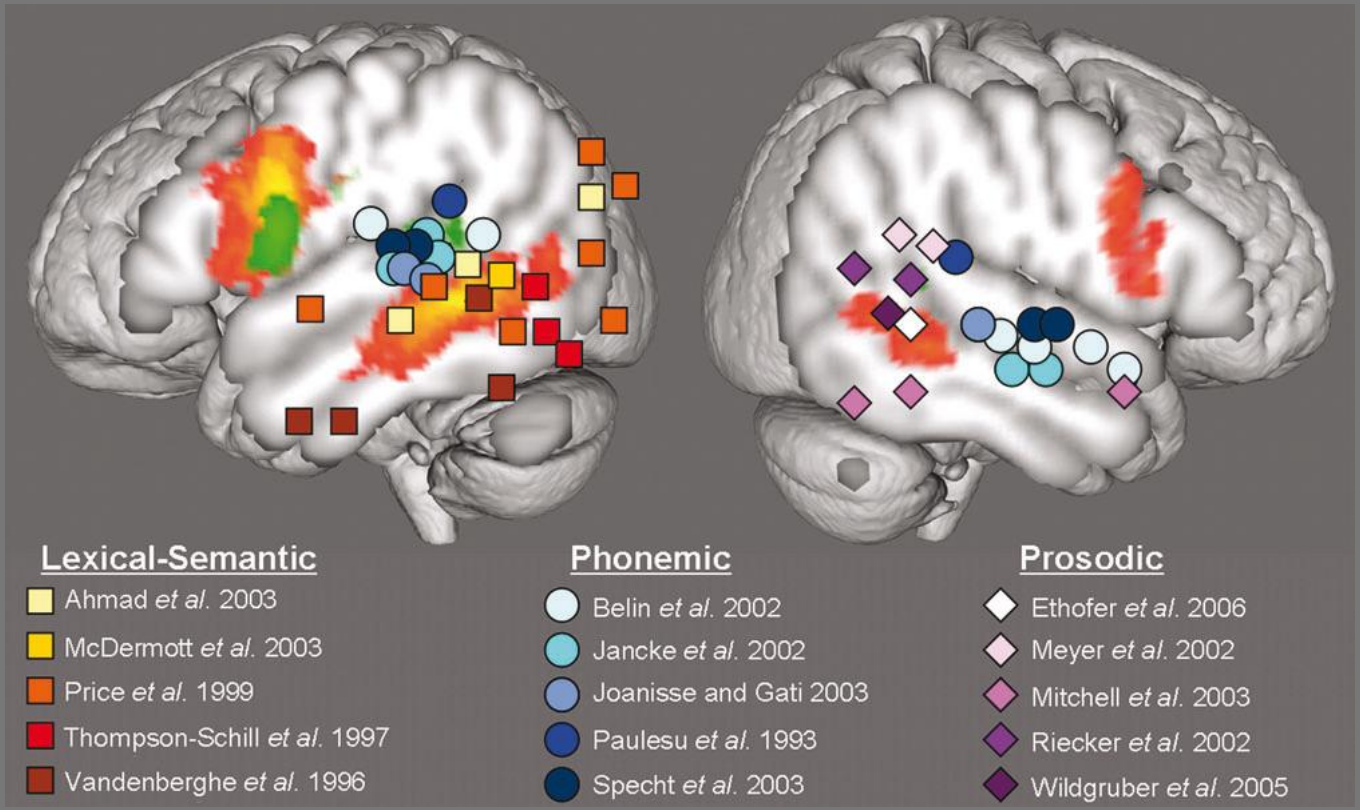
# Perisylvian fibre tracks




Anwander et al. (2007), Cereb Cortex

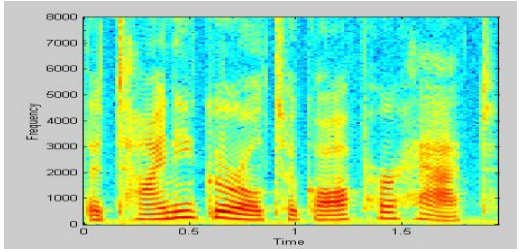
# „Division of labor“



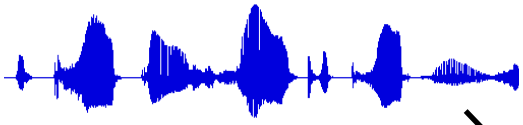

Glasser & Rilling (2008), Cerebral Cortex

# From vibrations of air to a linguistic representation in the brain

**Sounds** **Speech**



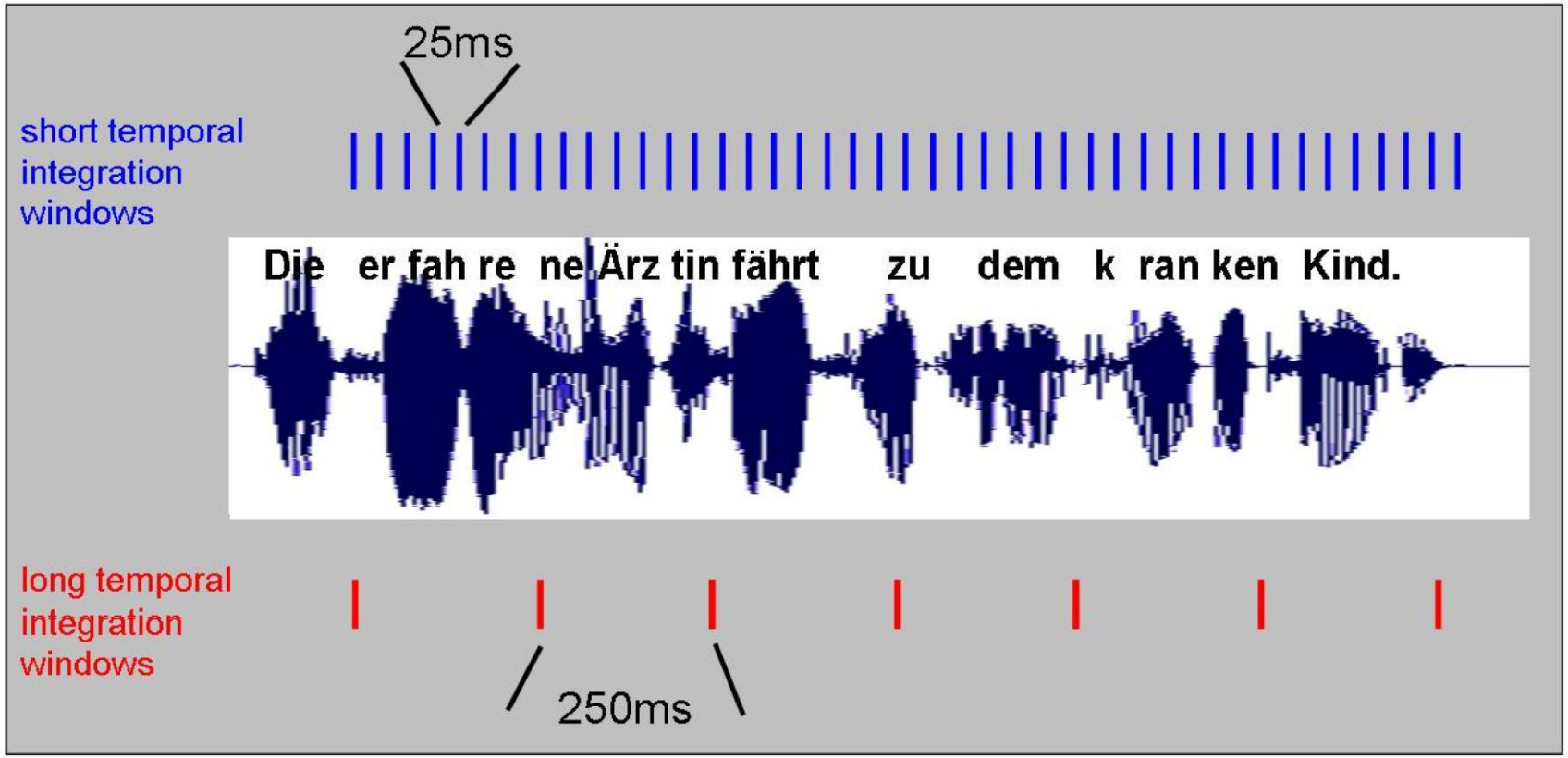

Continuously varying sounds made up of spectrotemporal patterns of differential complexity ...



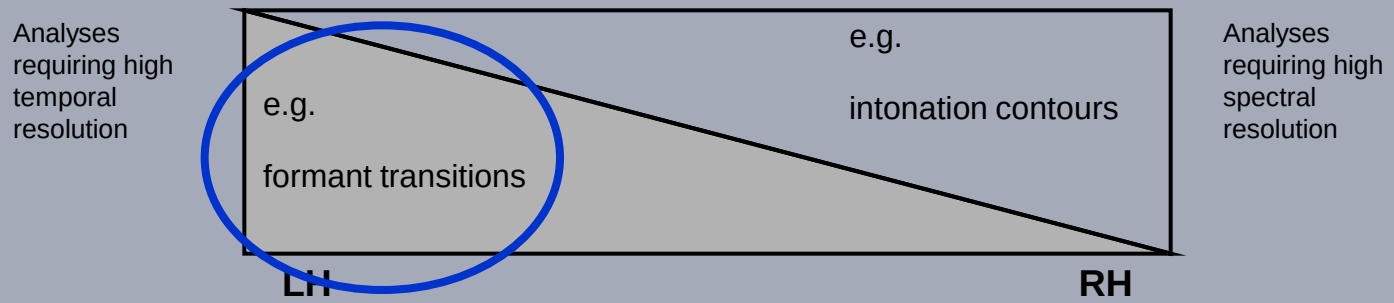
... Have to be recognized as “speech” and transferred to higher language regions ...

so that we are able to construe a spoken utterance.

## Multiresolution sampling/quantization of the speech waveform




Meyer, Z Neuropsy (2008)

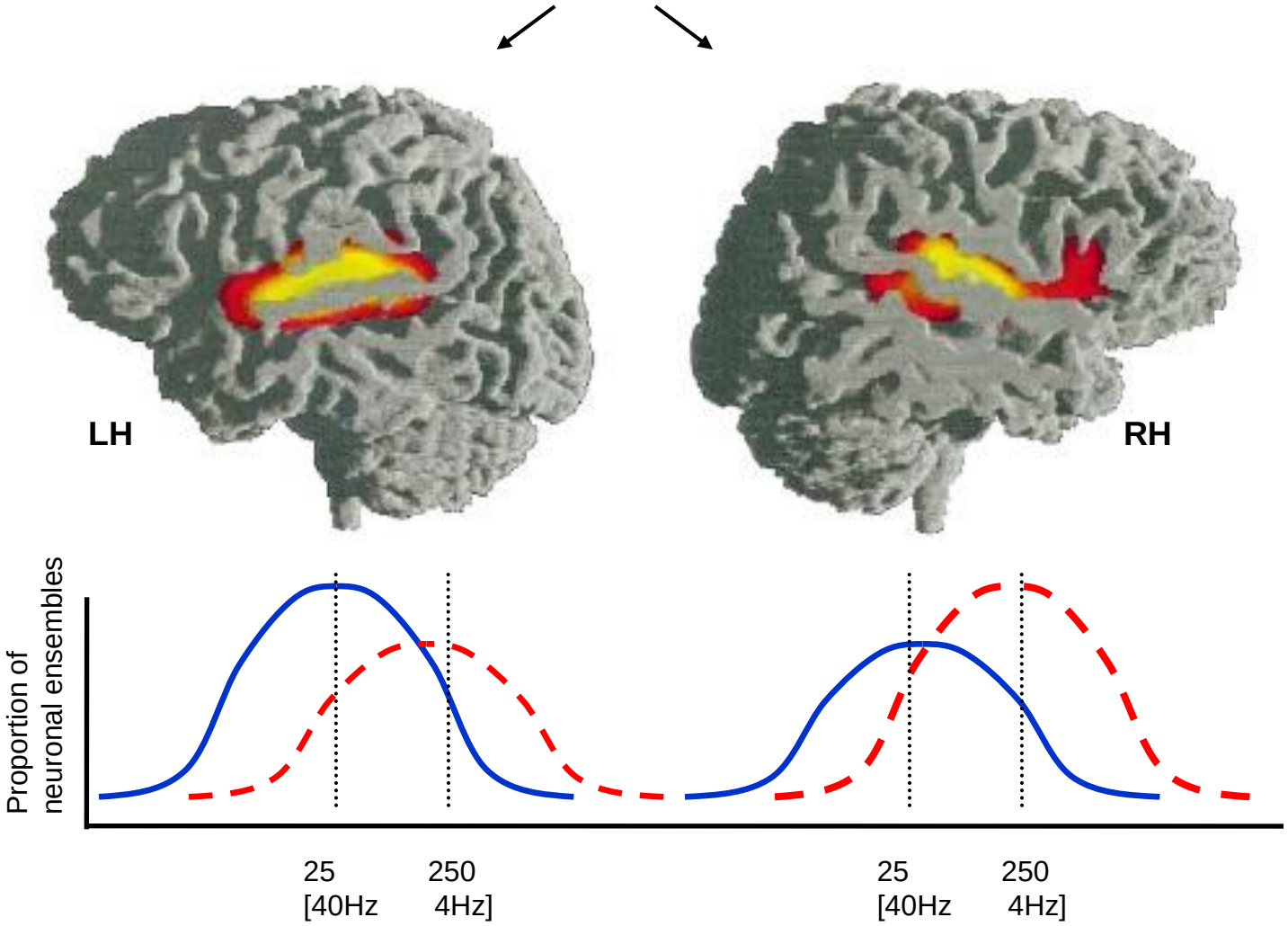


# Asymmetric sampling in time (Poeppel 2003)

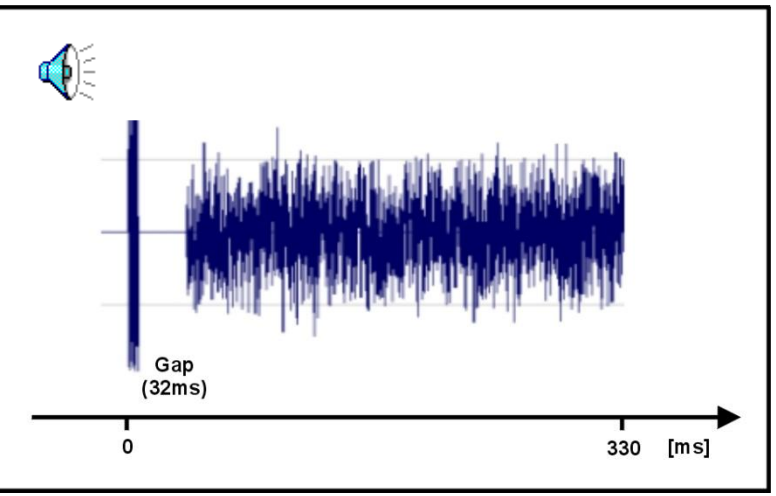
**Symmetric representation of spectro-temporal receptive fields in primary auditory cortex**

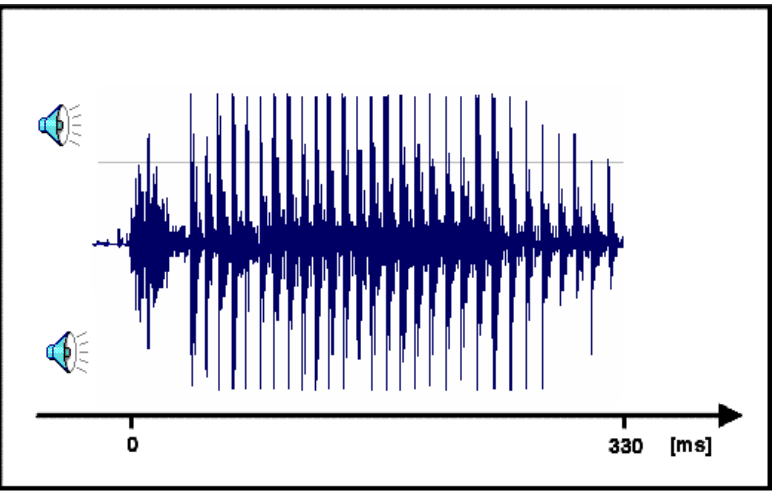
↓

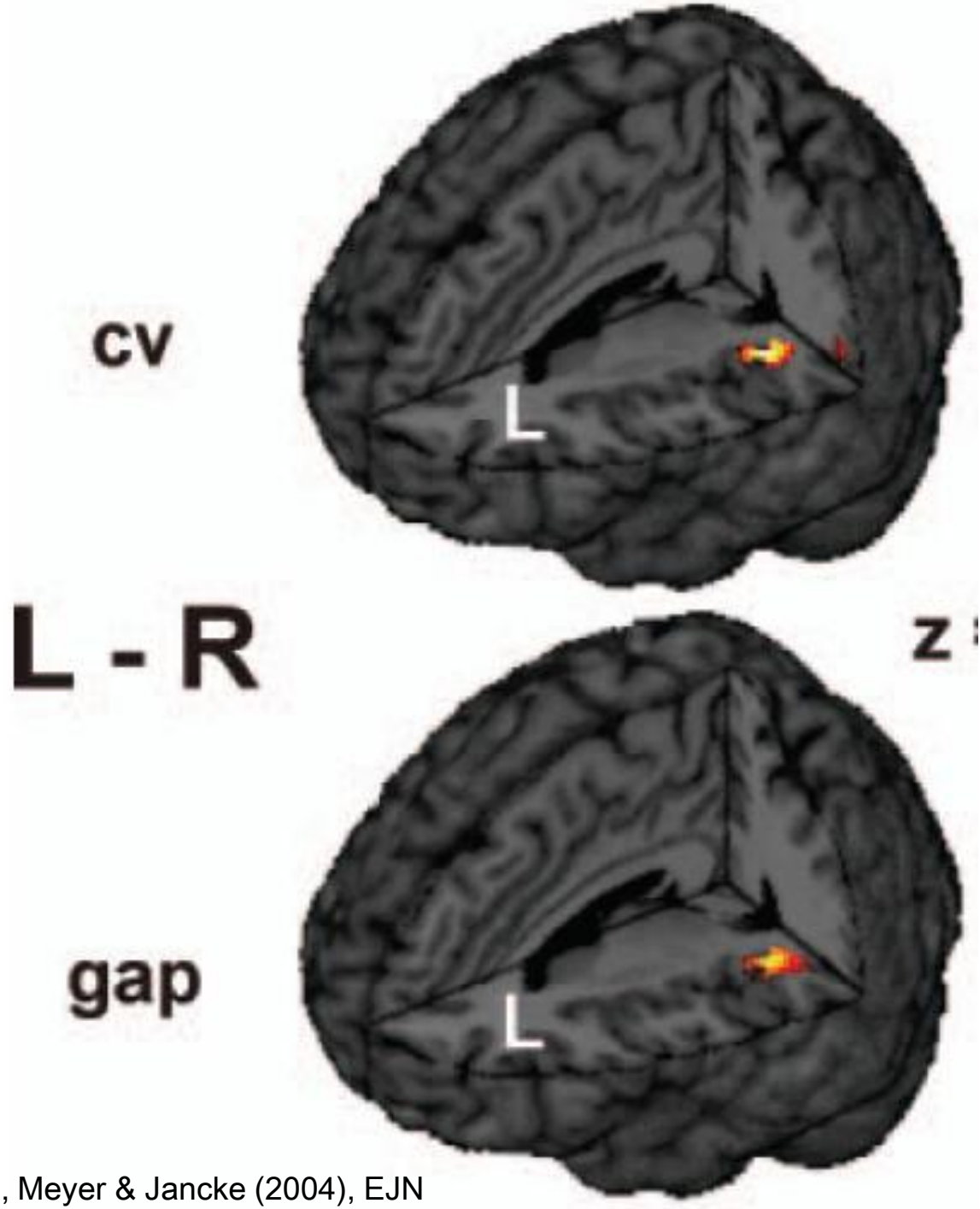
**Temporally asymmetric elaboration of perceptual representations in non-primary cortex**




With courtesy of David Poeppel

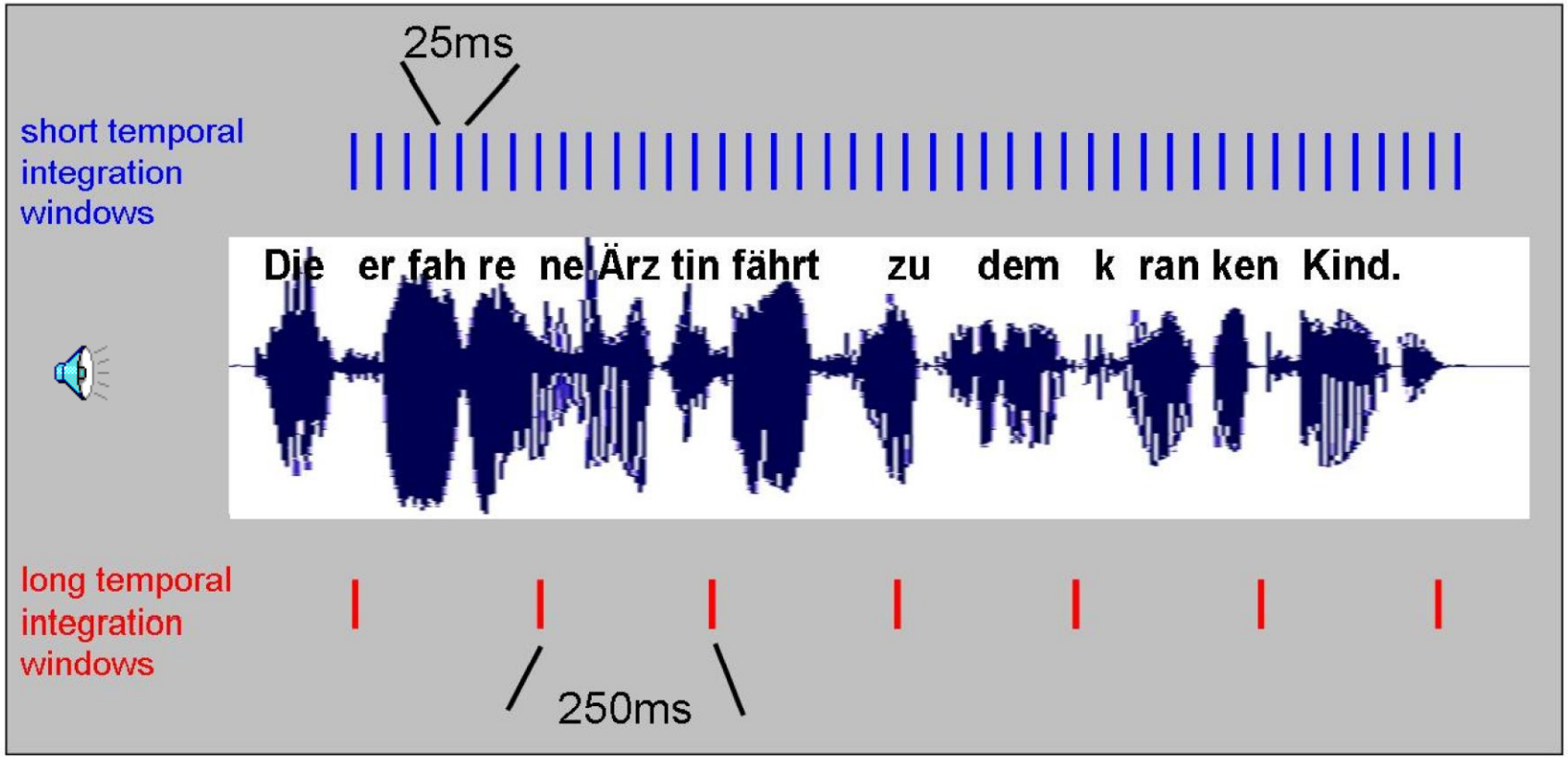


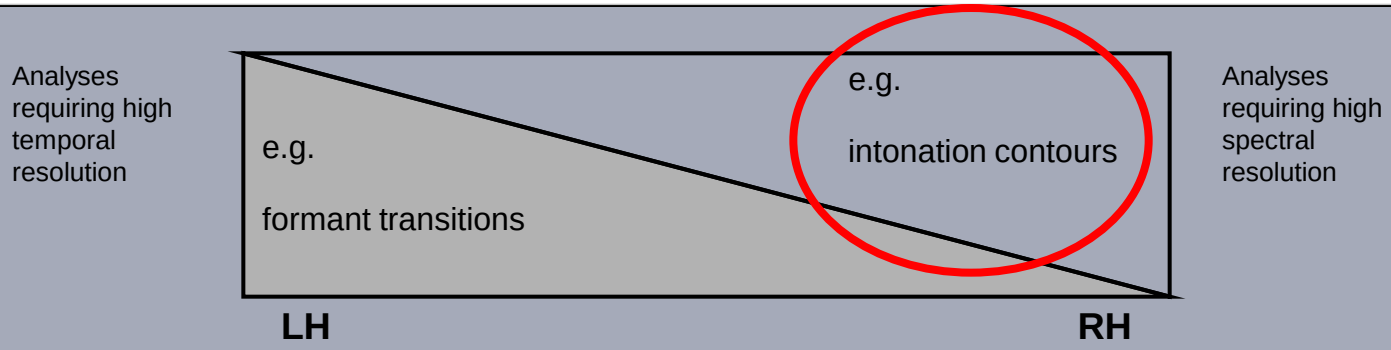




Zaehle, Wüstenberg, Meyer & Jancke (2004), EJN

## Multiresolution sampling/quantization of the speech waveform




Meyer, Z Neuropsy (2008)

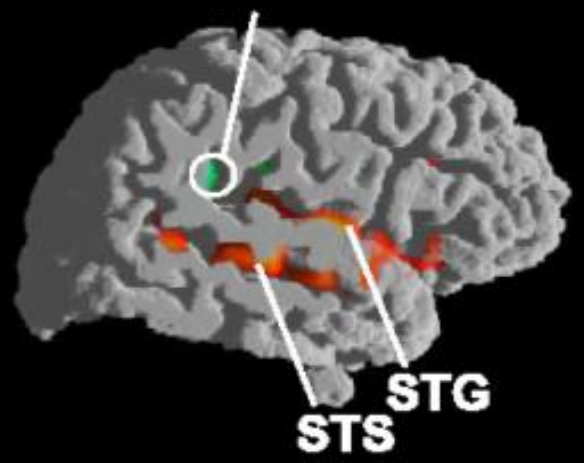


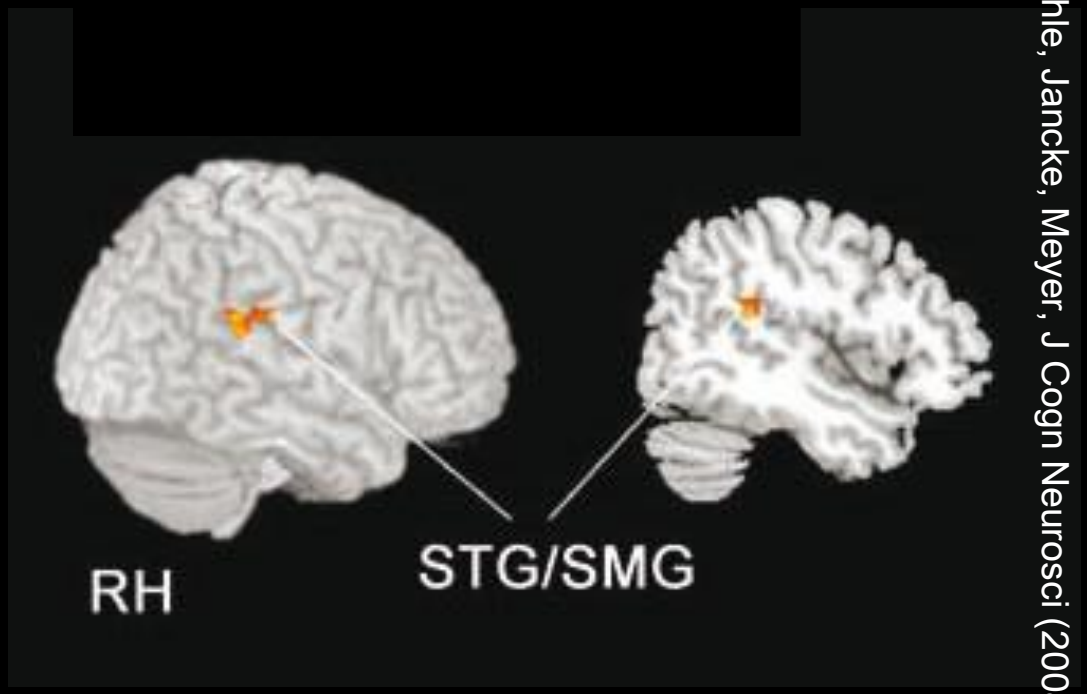
# Suprasegmental speech recognition: Prosody and Rhythm

Melodic contour vs monotonous speech

Metric vs nonmetric sentences

Planum parietale

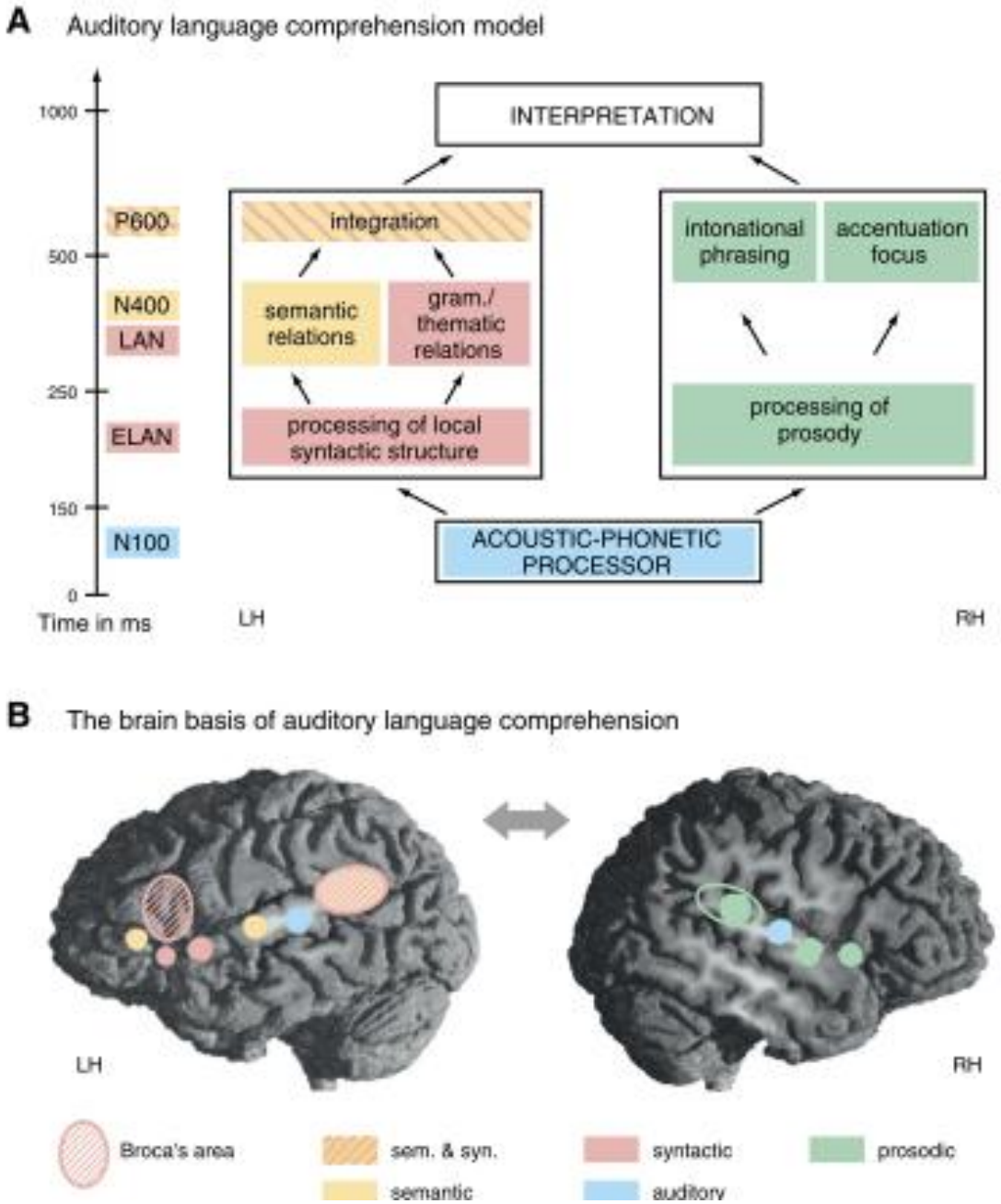



Meyer, Steinahuer, Alter, Friederici, von Cramon (2004), Brain and Language

Geiser, Zaehle, Jancke, Meyer, J Cogn Neurosci (2008)

Functional rightward asymmetry for slowly changing acoustic cues




Friederici (2011), Physiol Rev

# Issues

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- Performance and Modality
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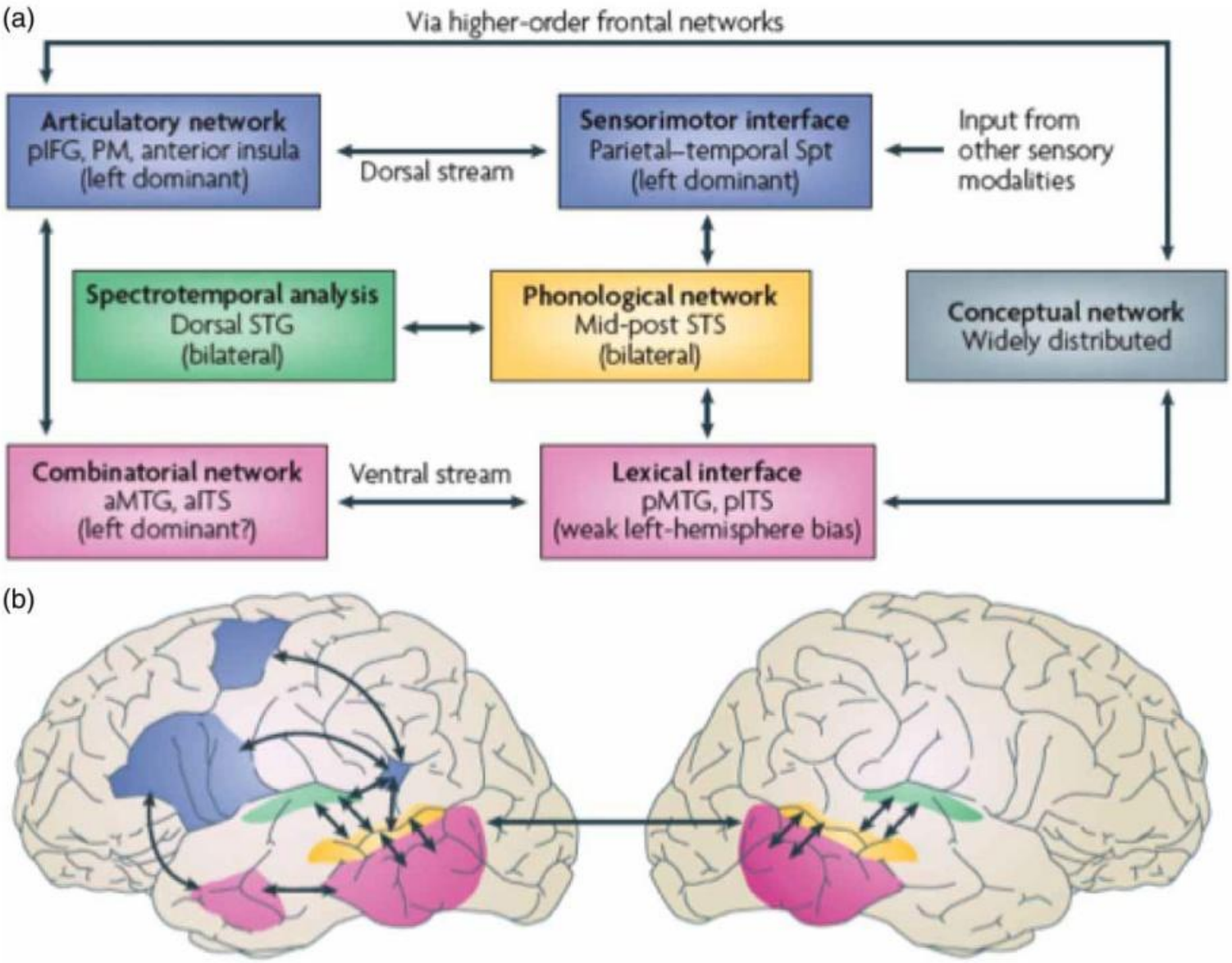
# Neurobiological framework of language comprehension

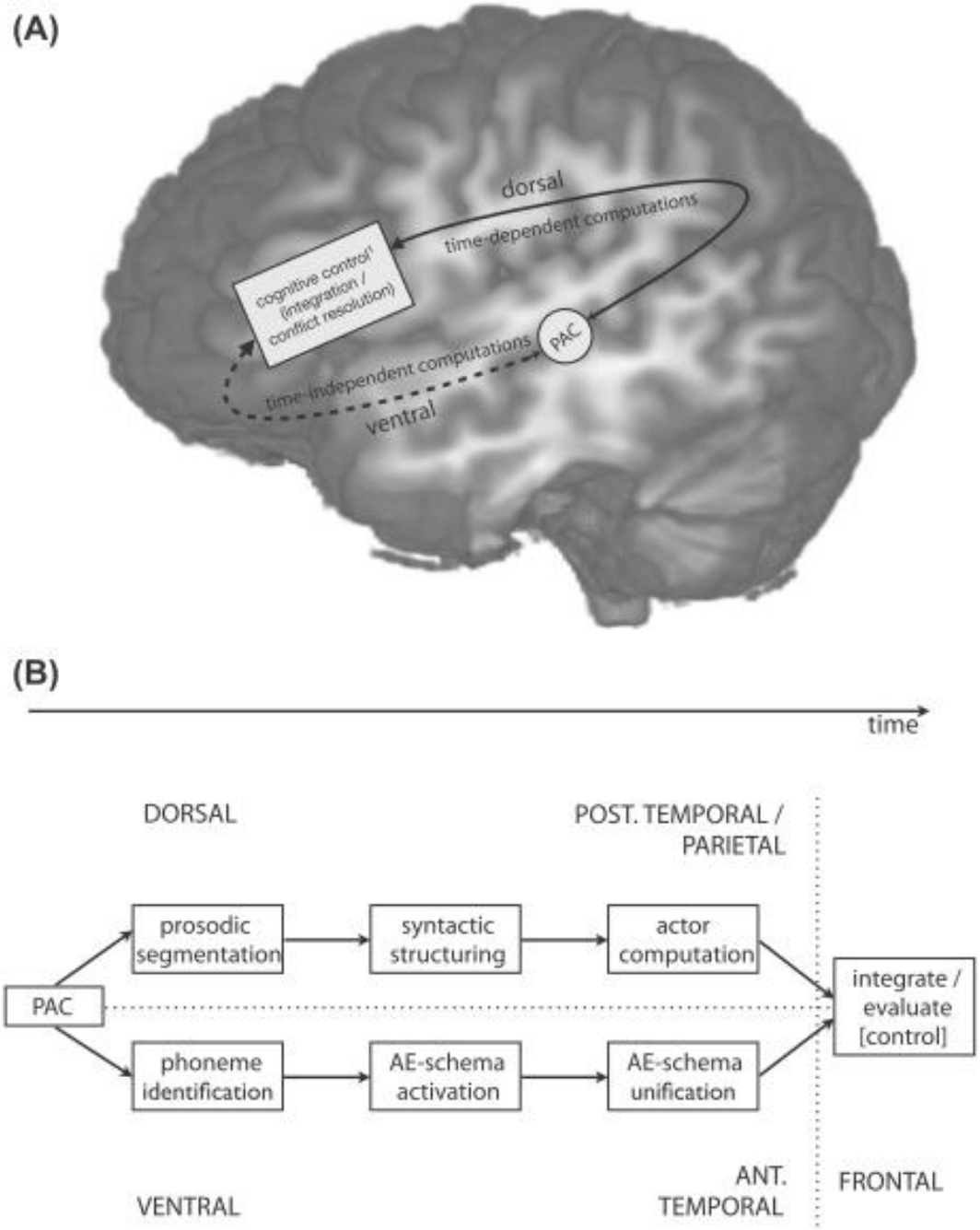



Poeppel (2012) Cog Neuropsychol

# A new dorsal-ventral stream of language comprehension

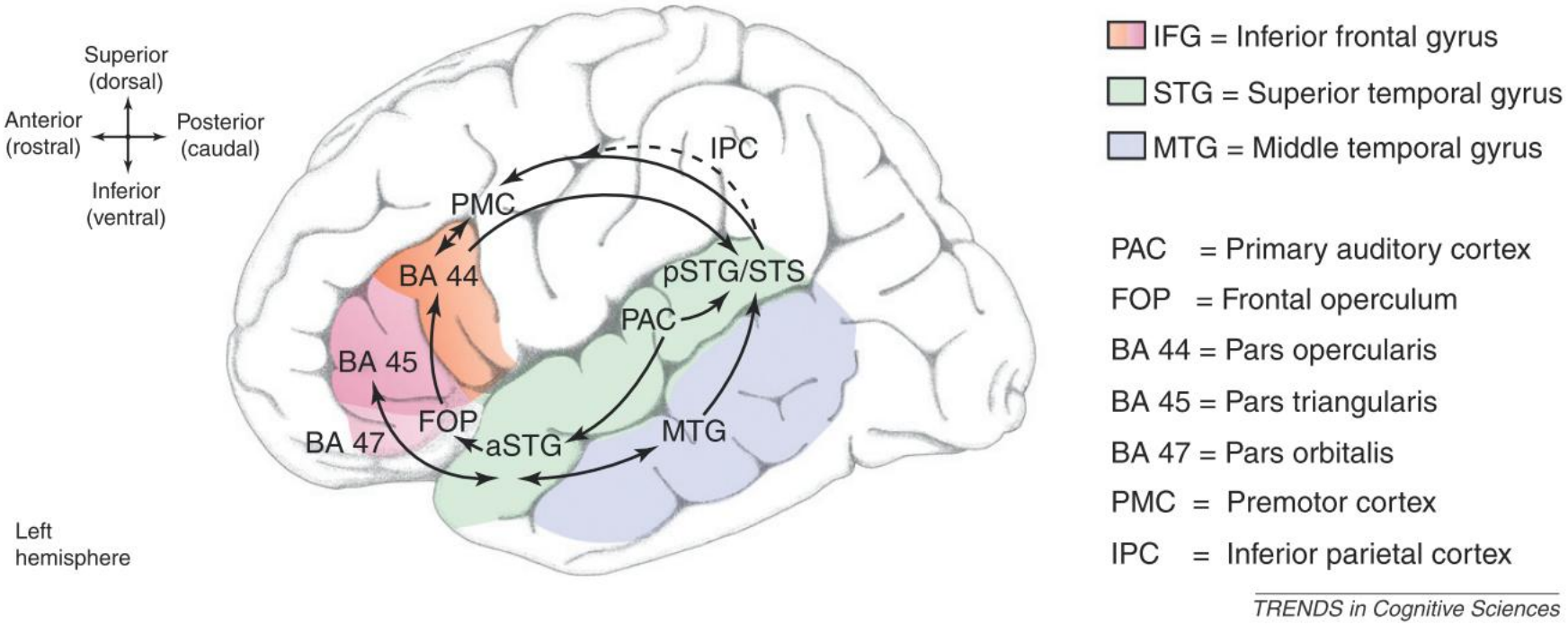
Hierarchical syntax => a gradient of cognitive control

Broca => links linguistic processing to behavior




Bornkessel-Schlesewsky & Schlesewsky (2013)

# The neural circuit of language comprehension




Friederici (2012), TICS

# Differential functional connectivity maps for distinct portions of the wide territory fomerly known as „Wernicke‘s“ area

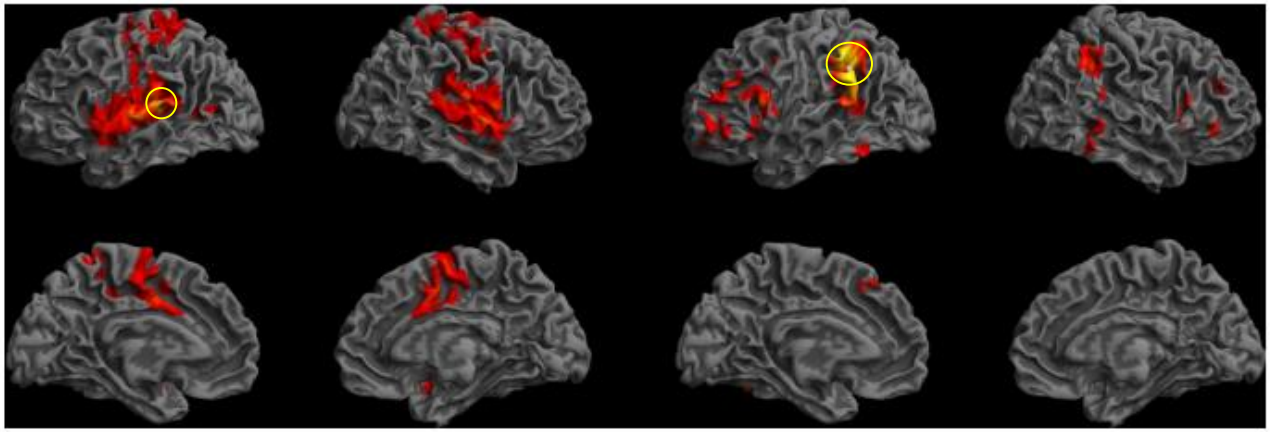


**FIGURE 15 | Resting-state functional connectivity maps for the left planum temporale (left) and the left posterior supramarginal gyrus (right) according to the Harvard–Oxford cortical atlas.** These maps suggest that the network associated with the posterior MTG is distinct from the networks that include the planum temporale and the posterior SMG. Colors indicate *t*-values (dark red = lowest, yellow-white = highest, with the voxels within the ROI showing the highest correlation).

Turken & Dronkers (2011)

# Résumé

- The classical model needs substantial revision or should be abandoned.
- Both the left and the right perisylvian cortex mediate speech and language comprehension (parameter-based division of labor).
- „Core language area“ in the left perisylvian region (subserving perception and production)
- Marginal differences across languages pertaining to neural implementation.
- Which language does the brain speak?

# Issues

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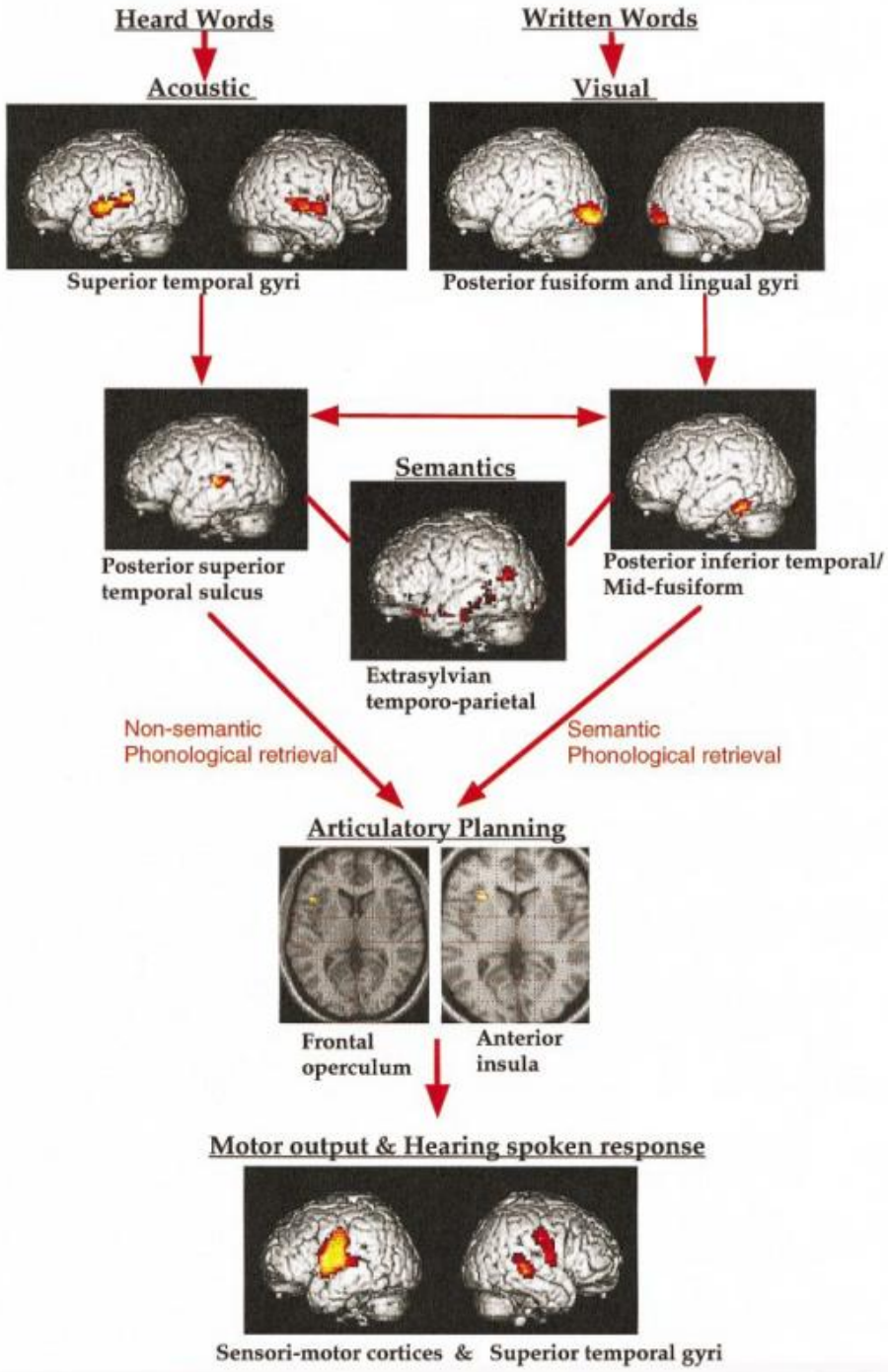
- Performance and Modality
- Division of labour between left and right hemisphere
- Current neurolinguistic models
- **Conceptual problems**

Price (2000), J Anat

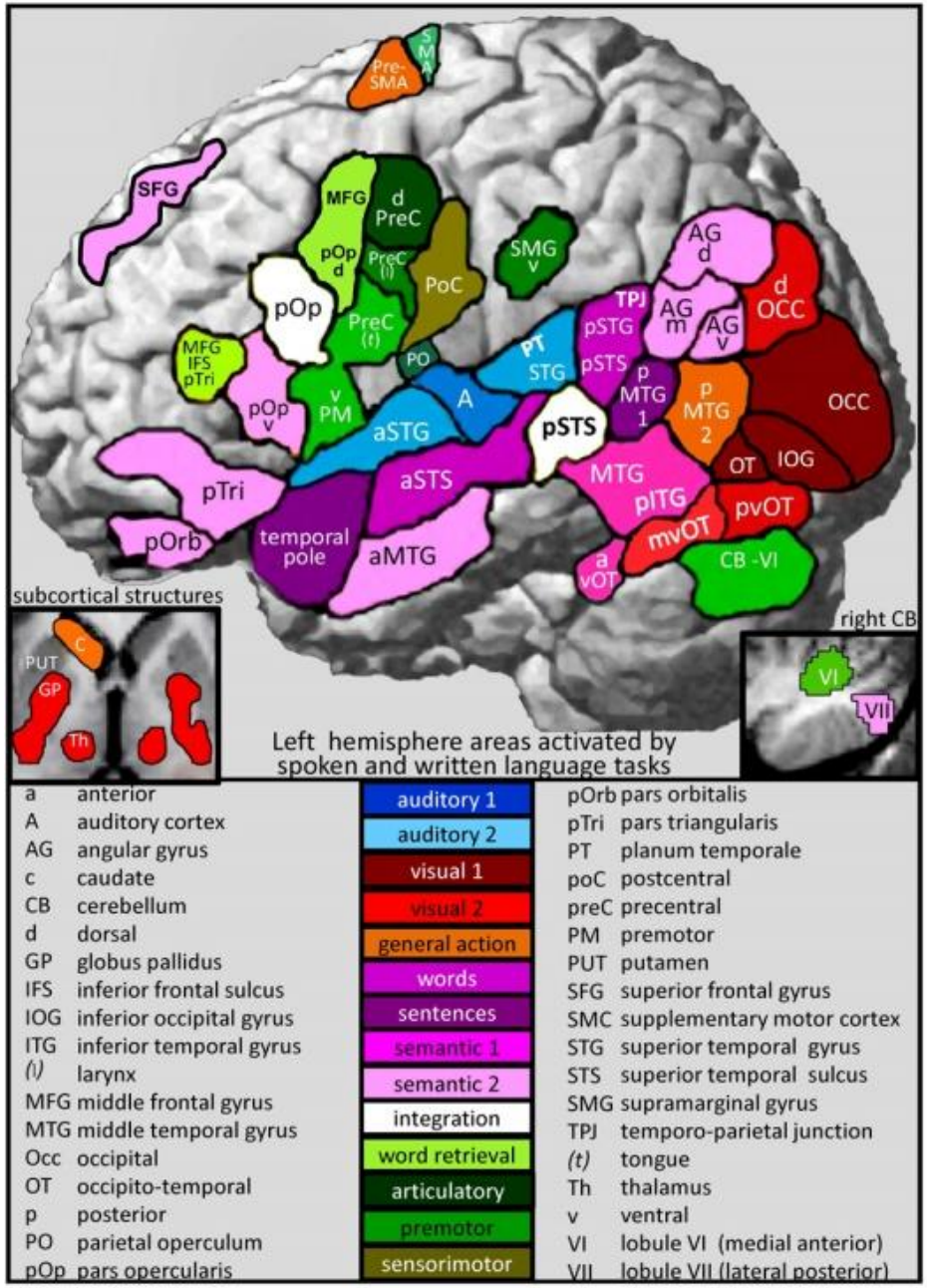



Proposed neurological and cognitive model of language

When neuroimaging is the answer …

What is the question ?

Price (2012), NeuroImage




When it comes to understanding how to relate … brain circuitry and cognitive faculties, we are in the dark”

Cedric Boeckx (2010)

We have very little to no idea as to how the stuff of thought relates to the stuff of brains, especially in the case of speech and language – and virtually all other cases

David Poeppel (2012)

# And how about the higher functions ?

**“granularity mismatch problem”:**

Elemental linguistic concepts more granular that elemental neurobiological concepts

„Syntax“ and „Semantics“ must not be considered monolithic systems that have a matching correspondence to brain systems that operate speech and language.

**“ontological incommensurability problem” :**

Uncertainty whether and to what extent subtle linguistic computations may match to neural computations or

whether there is a principle incommensurability problem that cannot be solved

Poeppel & Embick (2005)

# For the pessimists …

We still have no idea regarding the underlying question of what special properties of the human brain allow it to support language, and what the distinctive properties (at the neuronal level) of the language areas (if such exist) are”

Boeckx (2010)

# The incommensurability problem

(Poeppel 2012)

| Linguistics | Neuroscience |
|---|---|
| ***Fundamental elements of representation (at a given analytic level)*** | |
| distinctive feature | dendrites, spines |
| syllable | neuron |
| morpheme | cell-assembly/ensemble |
| noun phrase | population |
| clause | cortical column |
| ***Fundamental operations on primitives (at a given analytic level)*** | |
| concatenation | long-term potentiation (LTP) |
| linearization | receptive field |
| phrase-structure generation | oscillation |
| semantic composition | synchronization |

**Special thanks to my colleagues**
**Martina Hurschler, Eveline Geiser & Tino Zaehle**


Before brain imaging always think of