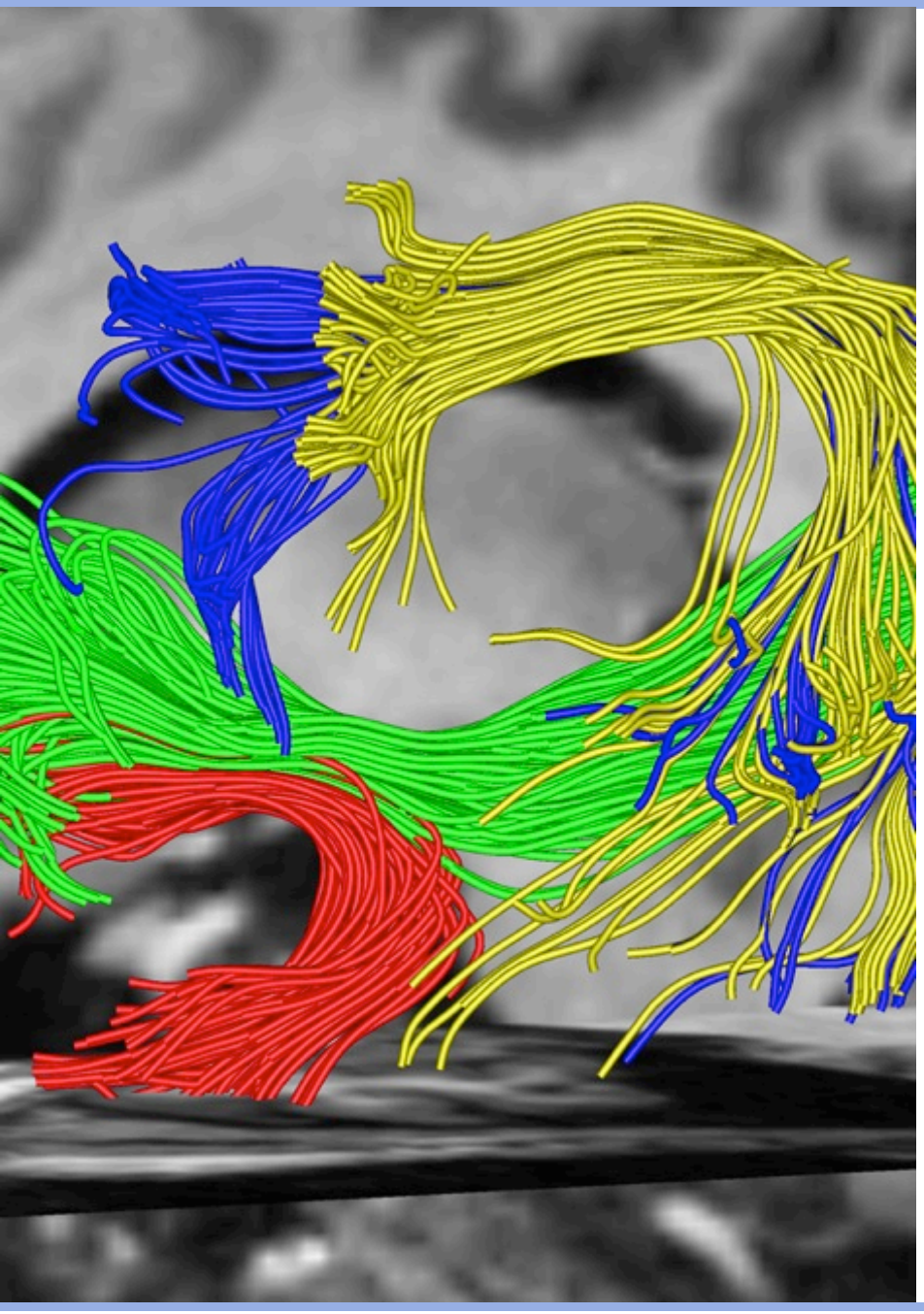

Grounding language on neurobiology

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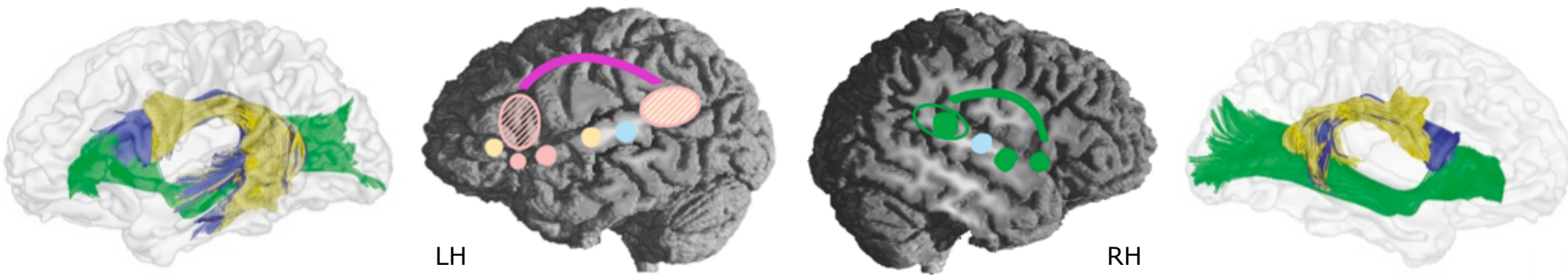
The language faculty is human specific. What is the neurobiological basis of this faculty?

courtesy of T. Fitch

Language in the human brain

Language is realized in the human brain as computations in specialized cortical areas that are tightly coupled functionally and structurally to form a large scale network for language processing. It receives its specificity due to syntax, a system of rules that permits the combination, organization and permutation of words in meta-structures, i.e. sentences.

Structure	Function	Function	Structure

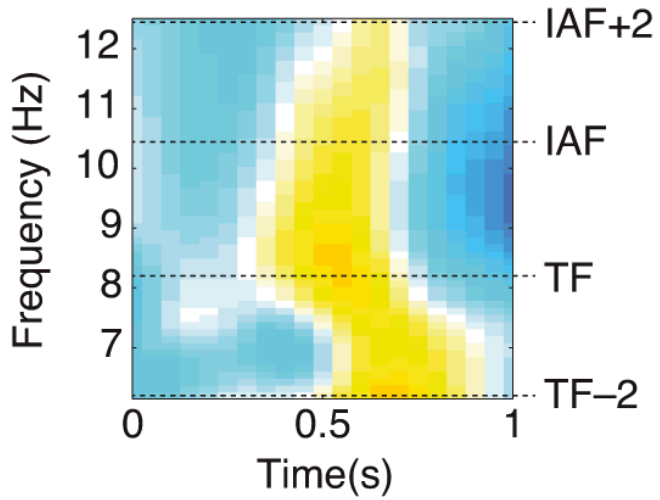


Source: Friederici, Physiological Reviews, 2011

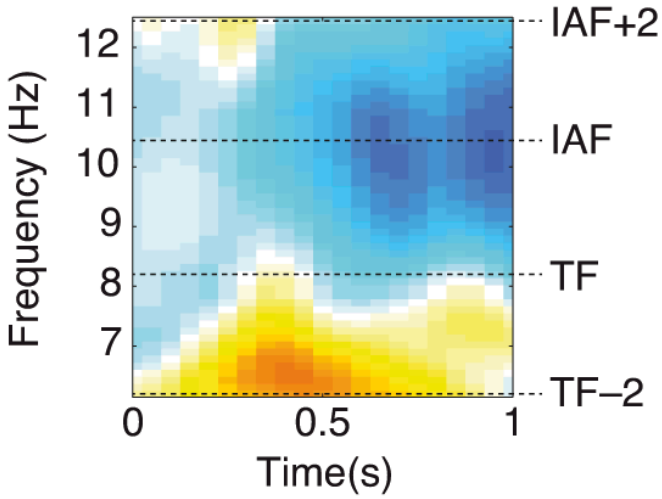
Basic neurophysiological principles

Although human specific, language is based on common neurophysiological principles. Individual neurons and neuronal assemblies are the basis of neuronal activity which for language usually can only be measured as spatiotemporal pattern at the cortical level (except for intracranial recordings).

Pattern for non-embedded sentences



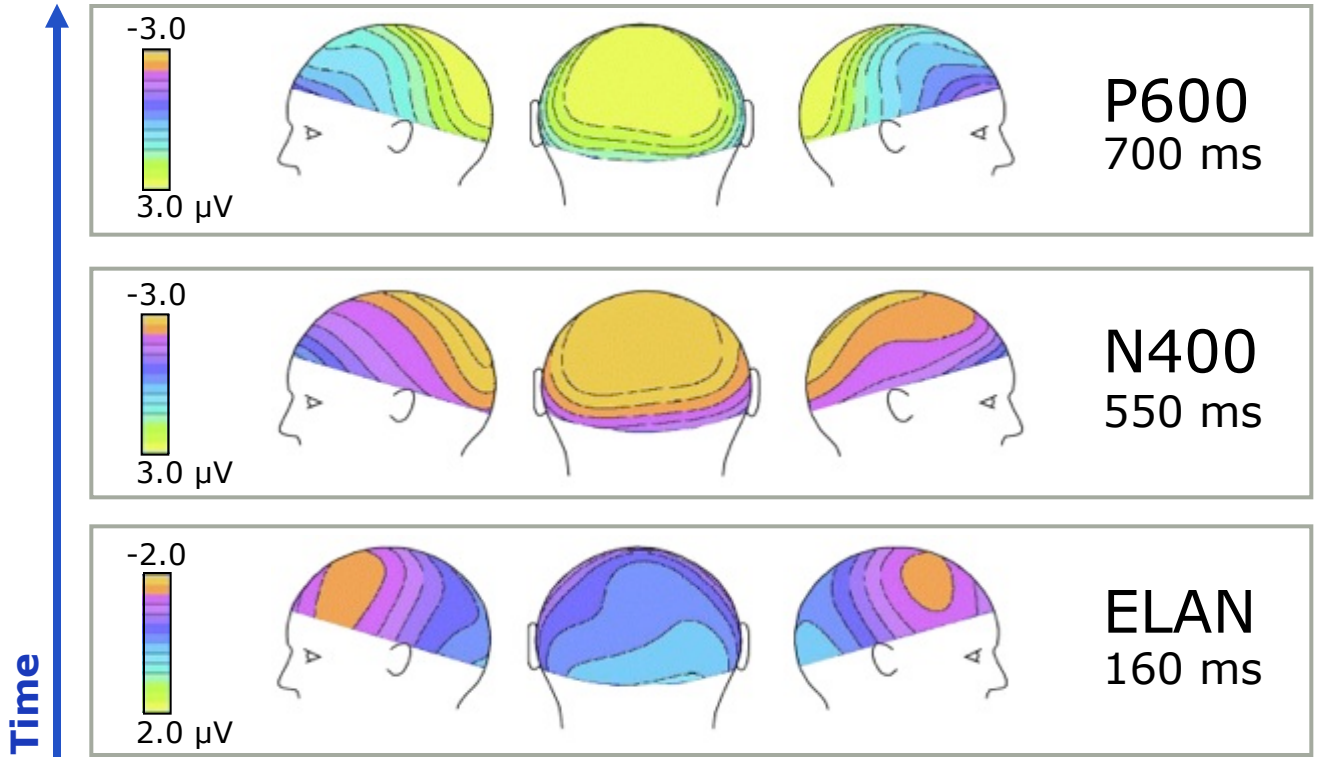
Pattern for embedded sentences

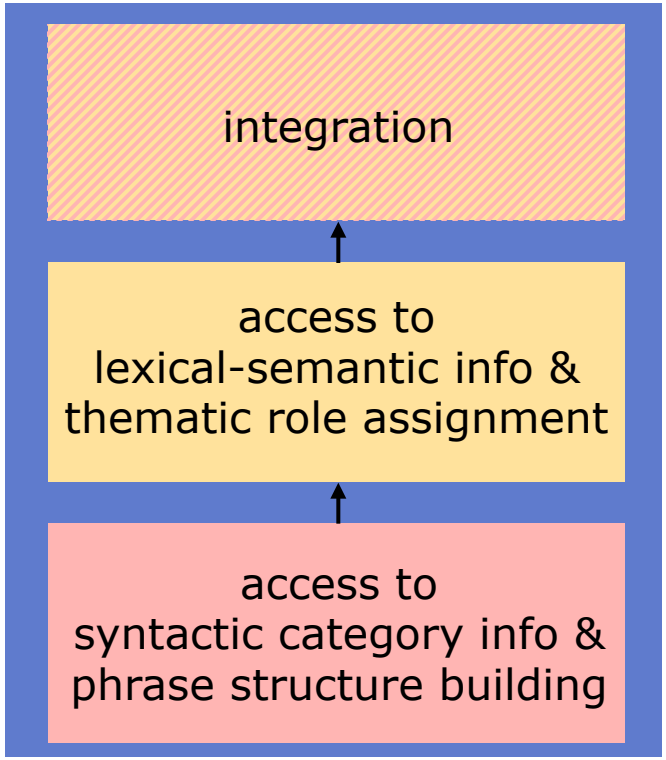


Source: Meyer, Grigutsch, Schmuck, Gaston & Friederici, Poster presented at CNS, 2014

EEG:Neurochronometry of language comprehension

EEG data have allowed to identify specific ERP components reflecting different aspects and levels during on-line sentence comprehension.

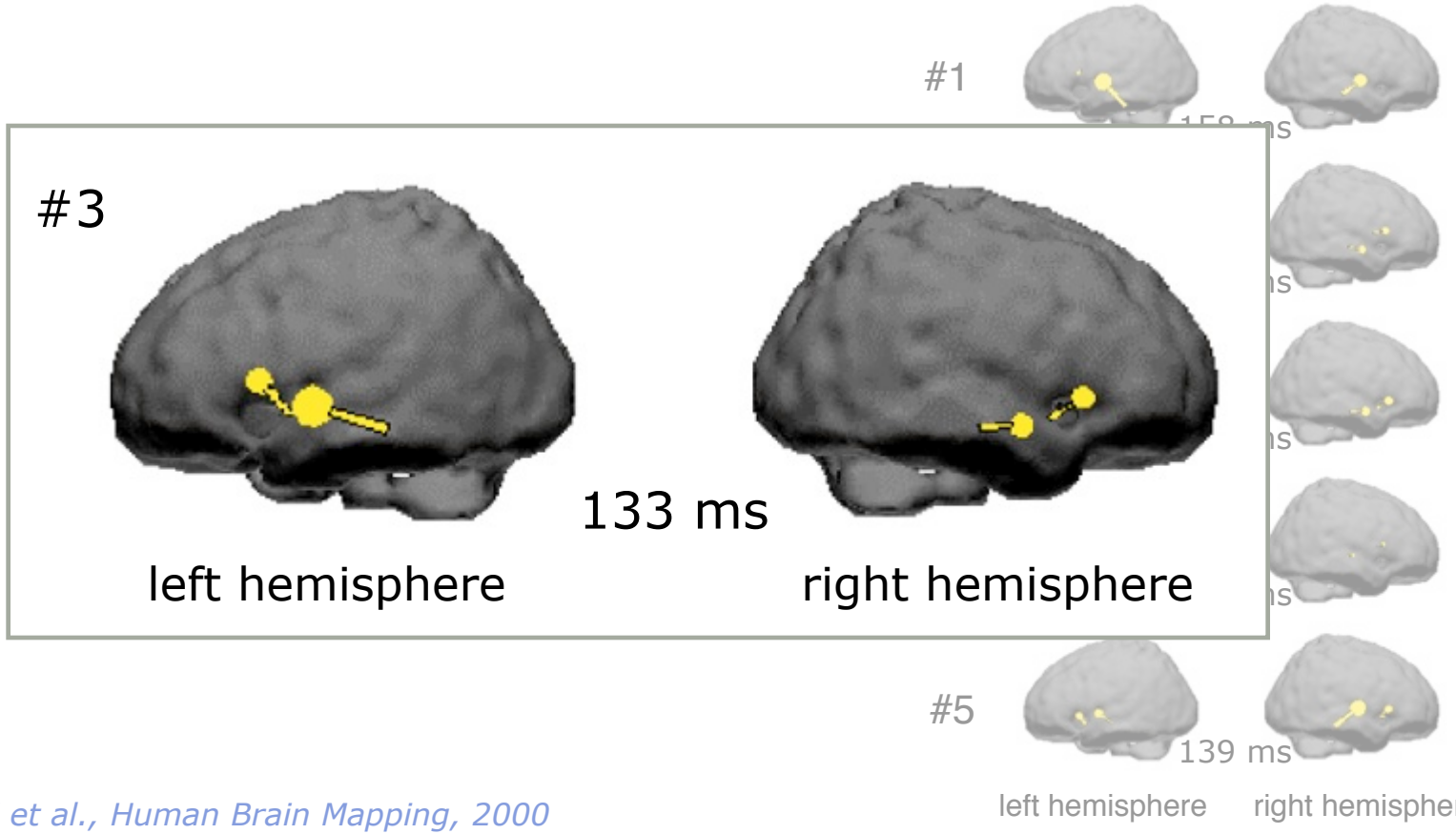




Source: 3-Phases Model by Friederici, Brain and Language, 1995; Trends in Cognitive Sciences, 2002

Phase 1: MEG localization of the ELAN

Using MEG the ELAN representing initial phrase structure processes could be localized in the anterior temporal and inferior frontal cortex.



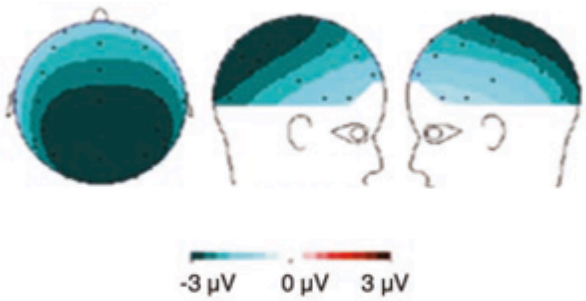
Source: Friederici et al., Human Brain Mapping, 2000

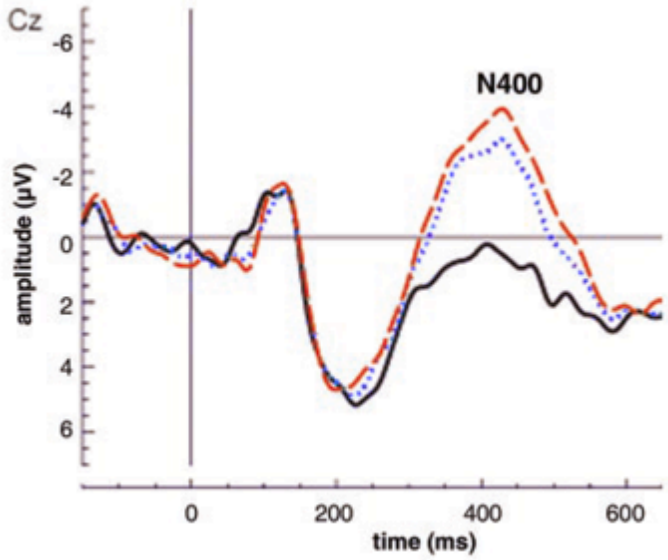
Phase 2: The N400 allows to differentiate different aspects

During sentence comprehension semantic and world knowledge are rapidly integrated in parallel.

Semantic N400-effect

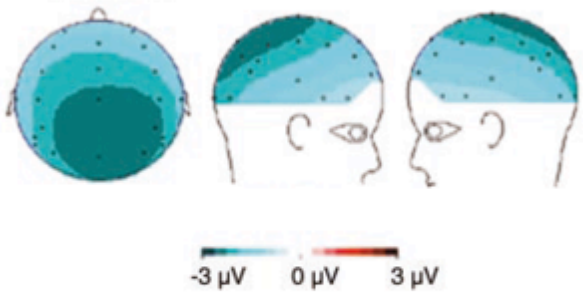
(300–550 ms)





World knowledge N400-effect

(300–550 ms)



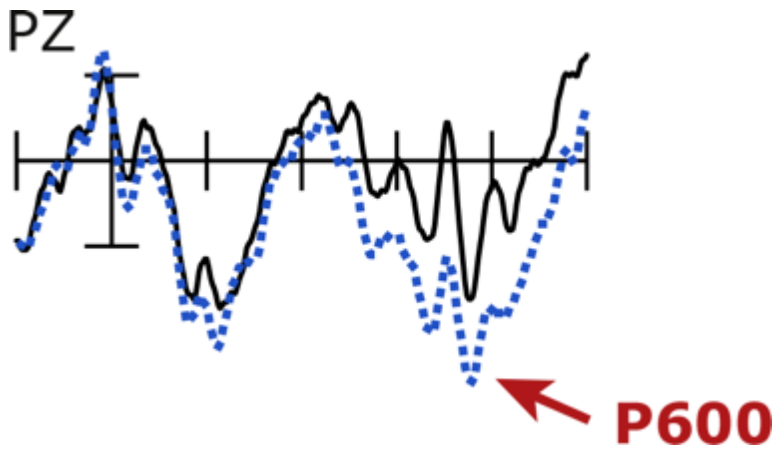
correct: The Dutch trains are yellow and very crowded.
world knowledge violation: The Dutch trains are white and very crowded.
semantic violation: The Dutch trains are sour and very crowded.

Source: Hagoort, Hald, Bastiaansen & Petersson, Science, 2004

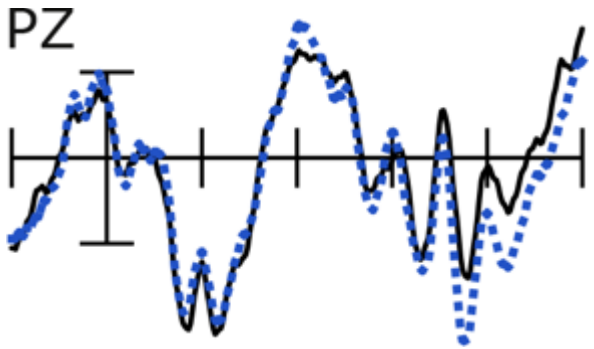
Phase 3: The integration phase: P600

Semantic and syntactic information interact during integration phase. The syntactic P600 is modulated by low cloze probability.

High cloze probability

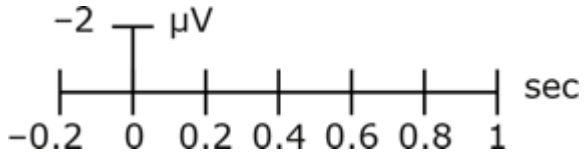


Low cloze probability



gender agreement

gender disagreement

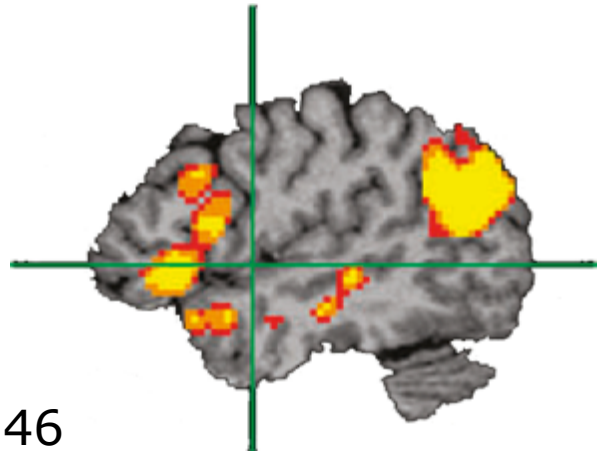


Source: Gunter, Friederici & Schriefers, Journal of Cognitive Neuroscience, 2000

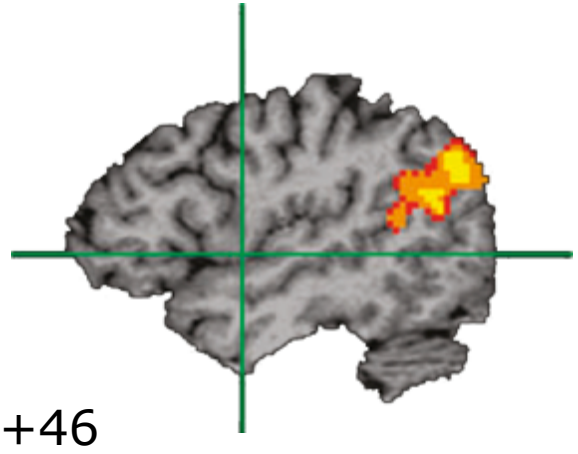
The semantic network

The semantic network has been demonstrated to be of considerable size, involving inferior frontal and temporal regions in both hemispheres.

Left hemisphere



Right hemisphere

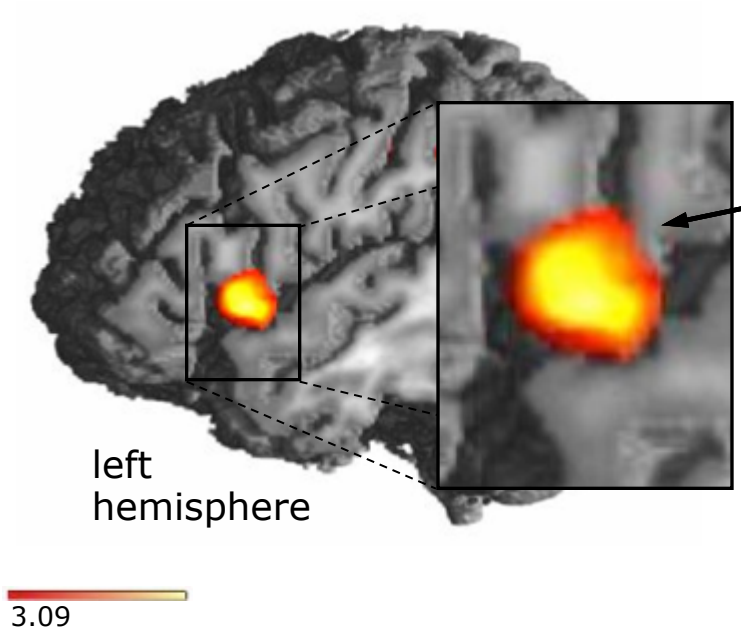


Source: Binder et al., Cerebral Cortex, 2009

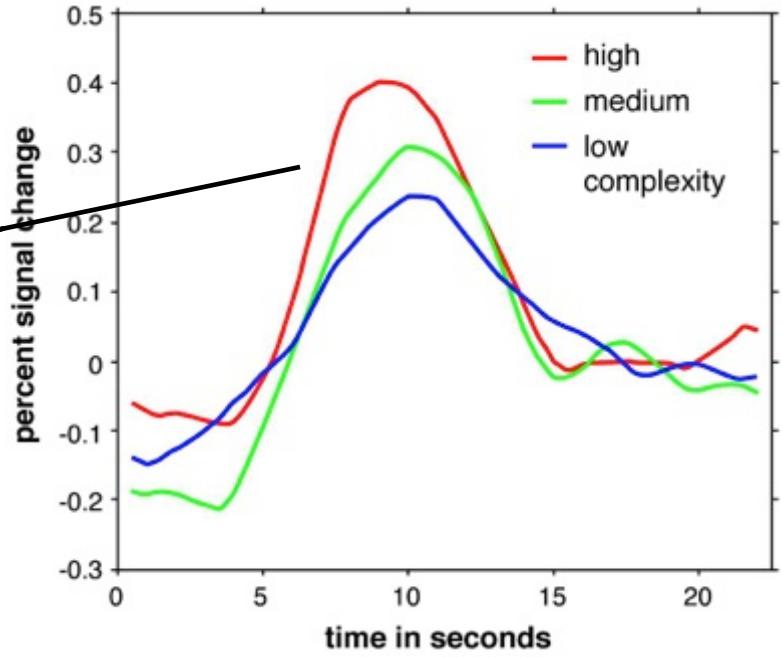
The syntactic network: Syntactic complexity

Functional subparts of the syntactic network are well localizable when well controlled stimulus material is used.

Broca's area



Complexity-activation

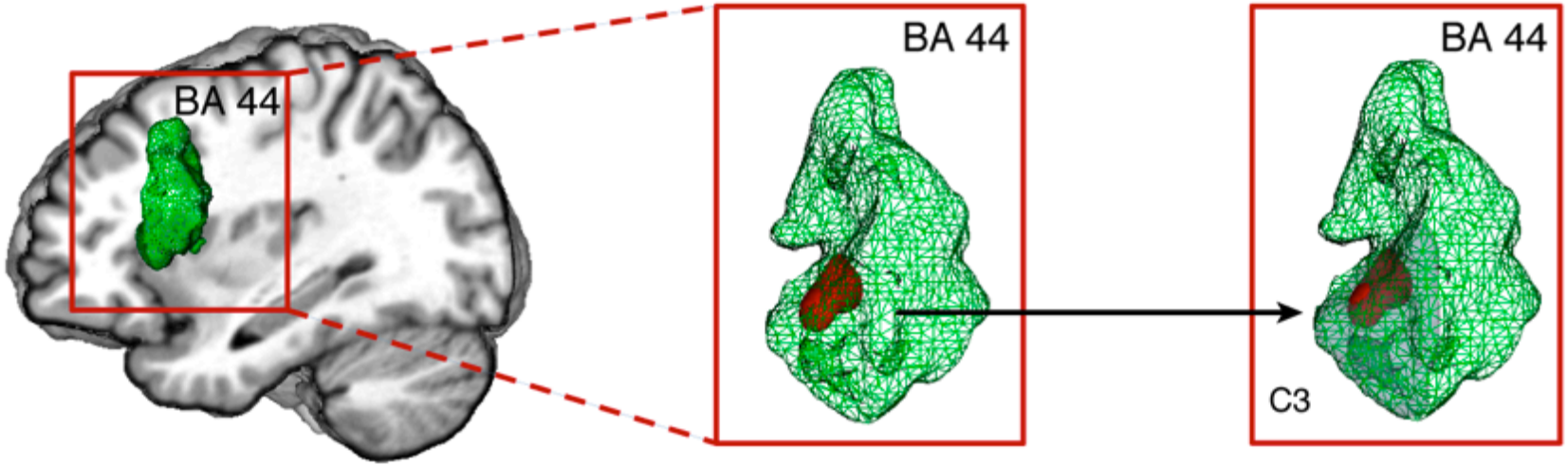


Source: Friederici et al., Cerebral Cortex, 2006

The syntactic network: Merge

Merge, the most basic syntactic operation of binding two elements together to form a phrase can be localized in a subpart of Broca's area, the ventral-anterior region C3.

Volume-of-interest	PH>LS activation	Mass localization with cluster overlap

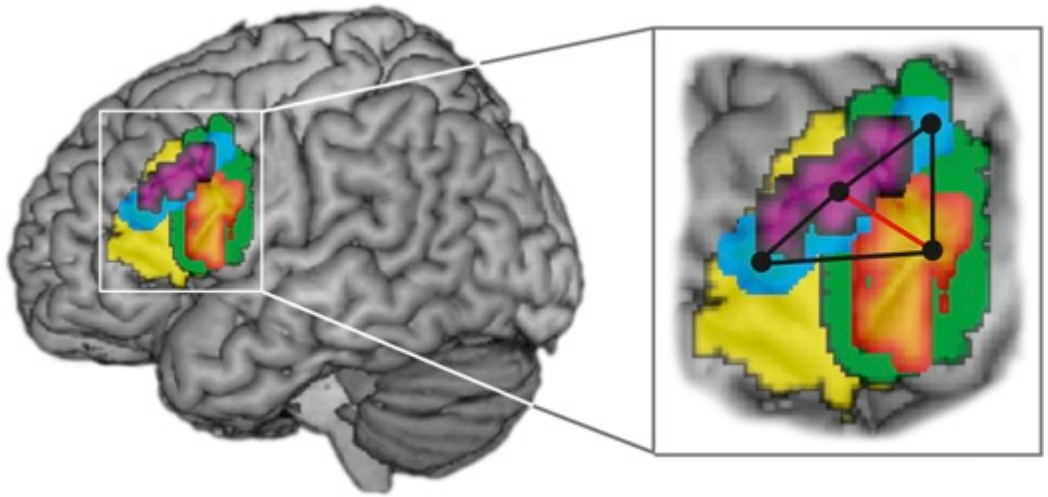


Source: Zaccarella & Friederici, Poster presented at FENS, 2013

Local syntactic network

Local syntactic network consist of BA 44 (syntactic hierarchy) and inferior frontal sulcus (syntactic WM). These regions interact during the processing of hierarchically structured sentences.

Processing embedded sentences



Orange: main effect of hierarchy

Light Blue: main effect of distance

Red: interaction

Yellow: BA 45

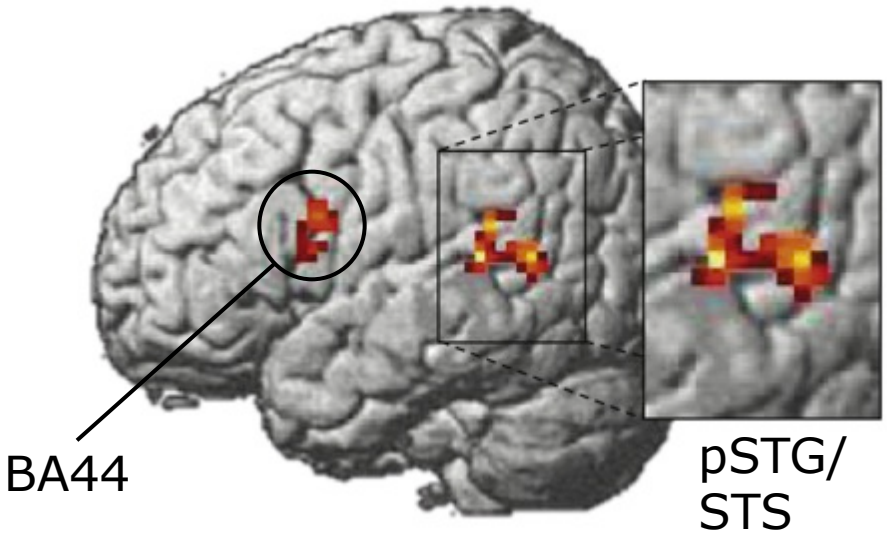
Green: BA

Source: Makuuchi, Bahlmann, Anwander & Friederici, PNAS, 2009

Long-range syntactic network

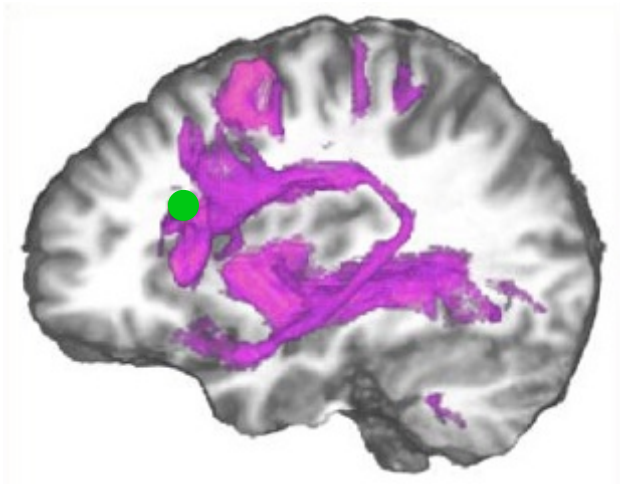
Long-range syntactic network consists of BA 44 (syntactic hierarchy), and pSTG/STS (integration).

Functional activation



Source: Friederici et al., NeuroReport, 2009

Structural connectivity



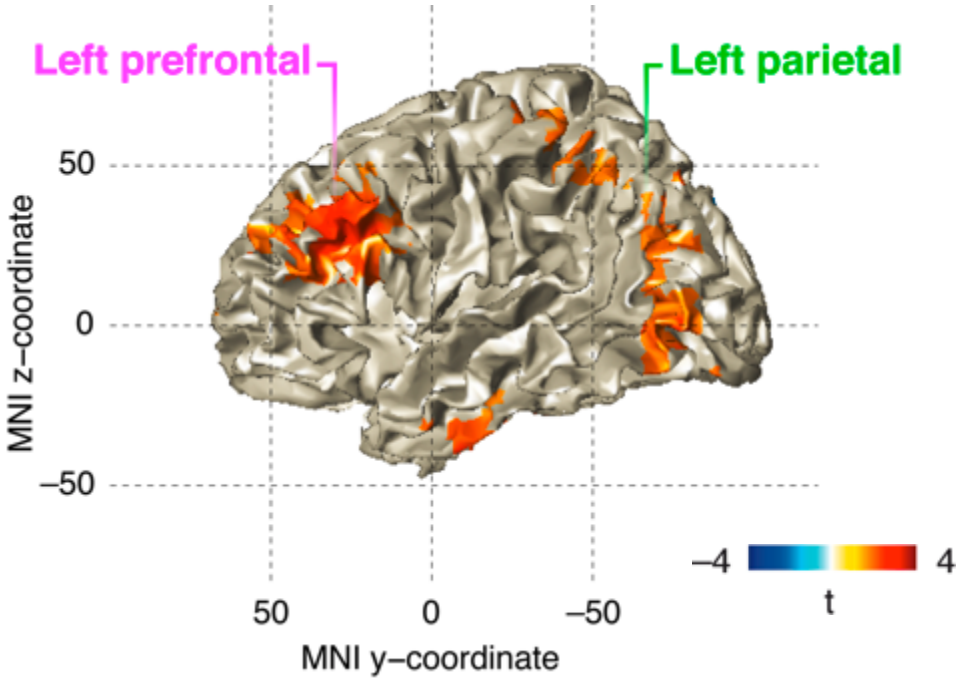
from BA44 to STG ● BA 44

Source: Friederici, Bahlmann et al., PNAS, 2006

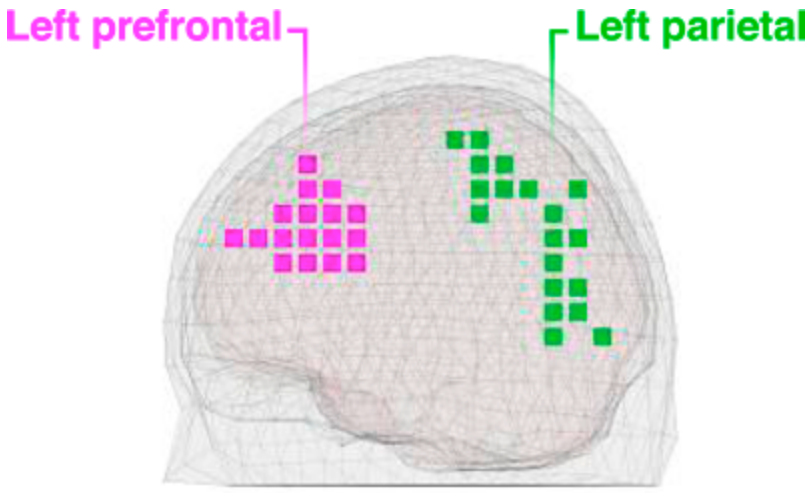
Neural synchronization within the syntactic network

The frontal and parietal/temporal region involved in syntactic processing synchronize (theta oscillations) during processing of syntactically complex sentences.

Source localization



Left frontal-parietal coherence



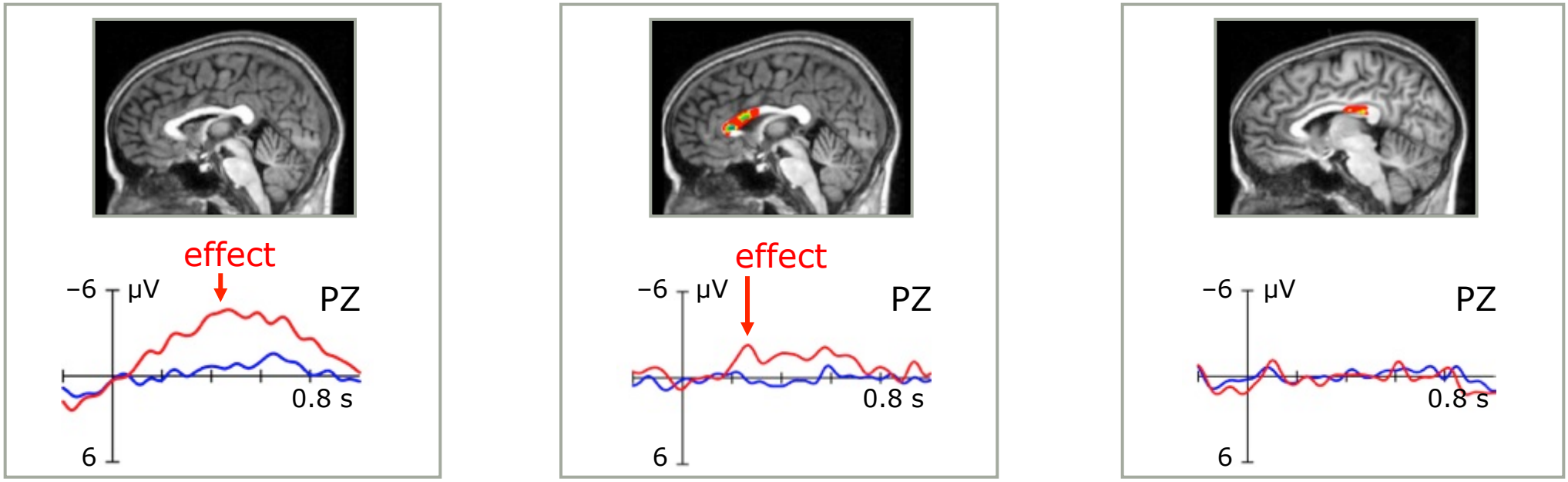
Theta synchronization

Sources: Meyer, Grigutsch, Schmuck, Gaston & Friederici, Poster presented at CNS, 2014

Syntax (LH) – Prosody (RH) – Interaction (CC)

Patients with lesions in the posterior Corpus Callosum do not show mismatch effect indicating that prosodic information (RH) cannot misguide the syntactic parser (LH).

Controls	Anterior CC lesion	Posterior CC lesion



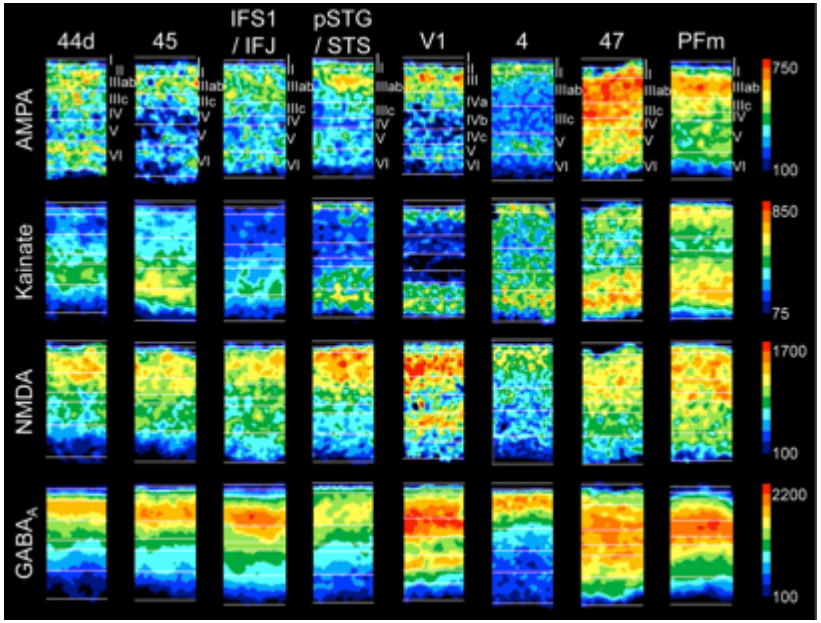
pros correct pros incorrect

Source: Friederici, Kotz & von Cramon, Neuron, 2007

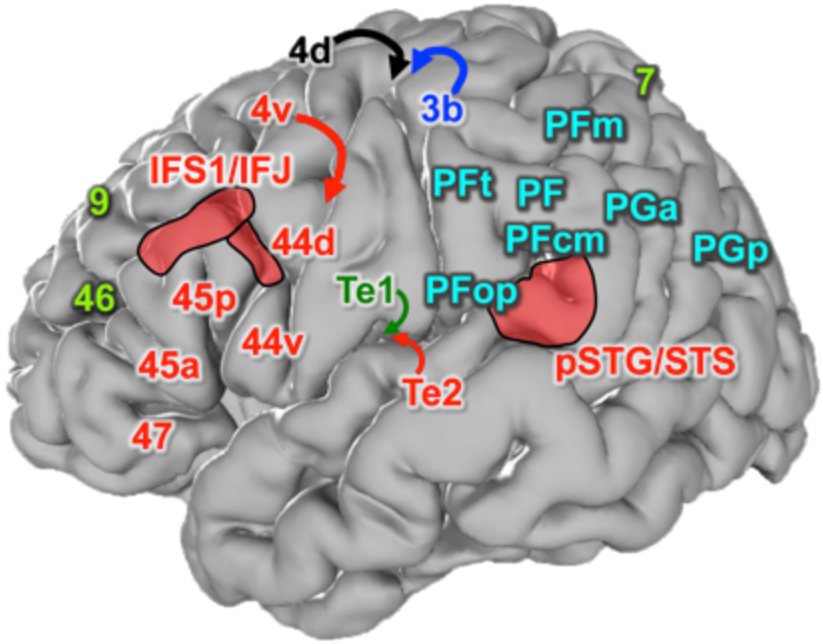
The language network at the molecular level

Areas that are part of the larger language network (red) may be neuroreceptorarchitectonically similar thereby providing a molecular basis for large-scale interaction.

Distribution of neuro-receptors



Red: Language network

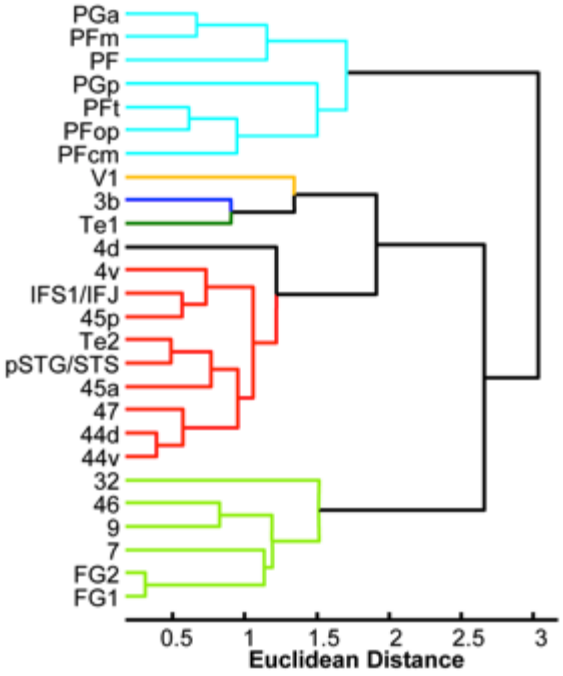


Sources: Zilles, Bacha-Trams, Palomero-Gallogher, Amunts & Friederici, Cerebral Cortex, 2015

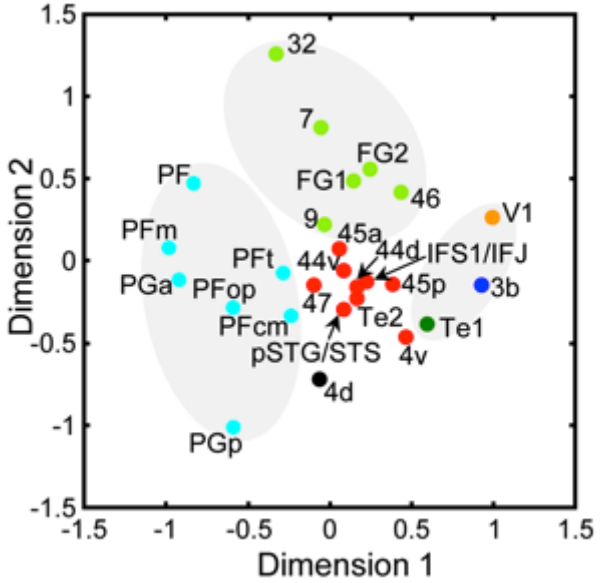
The language network at the molecular level

Areas that are part of the language network show a more similar multi-receptor organisation compared to other regions.

Hierarchical cluster tree



Multidimensional scaling



Sources: Zilles, Bacha-Trams, Palomero-Gallogher, Amunts & Friederici, Cerebral Cortex, 2015

Conclusion I

All the different levels of neurobiological analyses are relevant for our understanding of the brain-language relationship.

Specific levels of description and their analytic methods should be applied for specific (linguistic) questions.

But unless these level-specific analyses stay informed about the other levels, they will not advance science in the neurobiology of language.

Conclusion II

Unless we – as those being interested in the brain-language relationship – do not learn to consider more than one level of neurobiological description, the scientific community will not recognize the importance of our work, which in the end is crucial for our understanding of what it means to be human.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