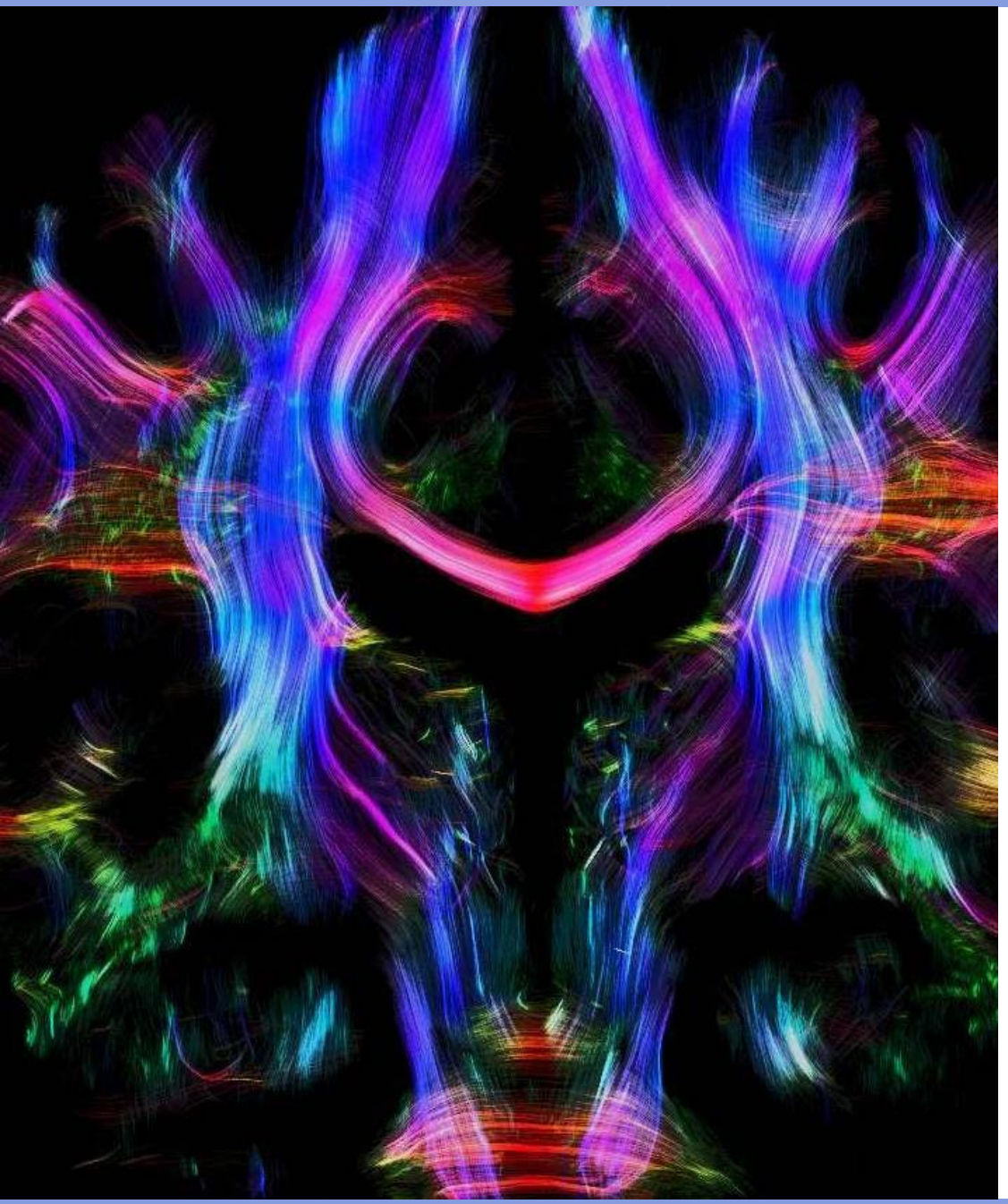


Native language and modality shapes structural connectivity in the brain

Alfred Anwander

Max Planck Institute
for Human Cognitive and Brain Sciences
Leipzig, Germany

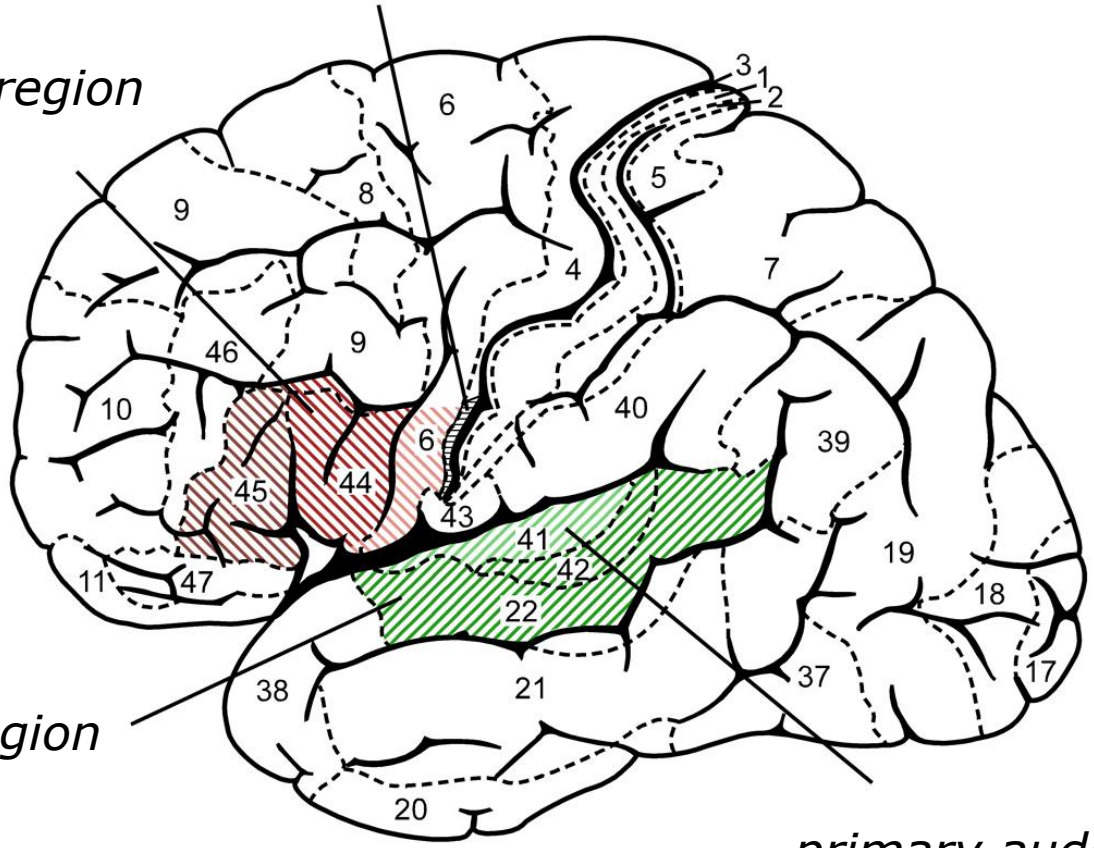
Language processing in the brain:
Classical language centers

Paul BROCA

1865

motor language region (Broca's area)

primary motor cortex



sensory language region (Wernicke's area)

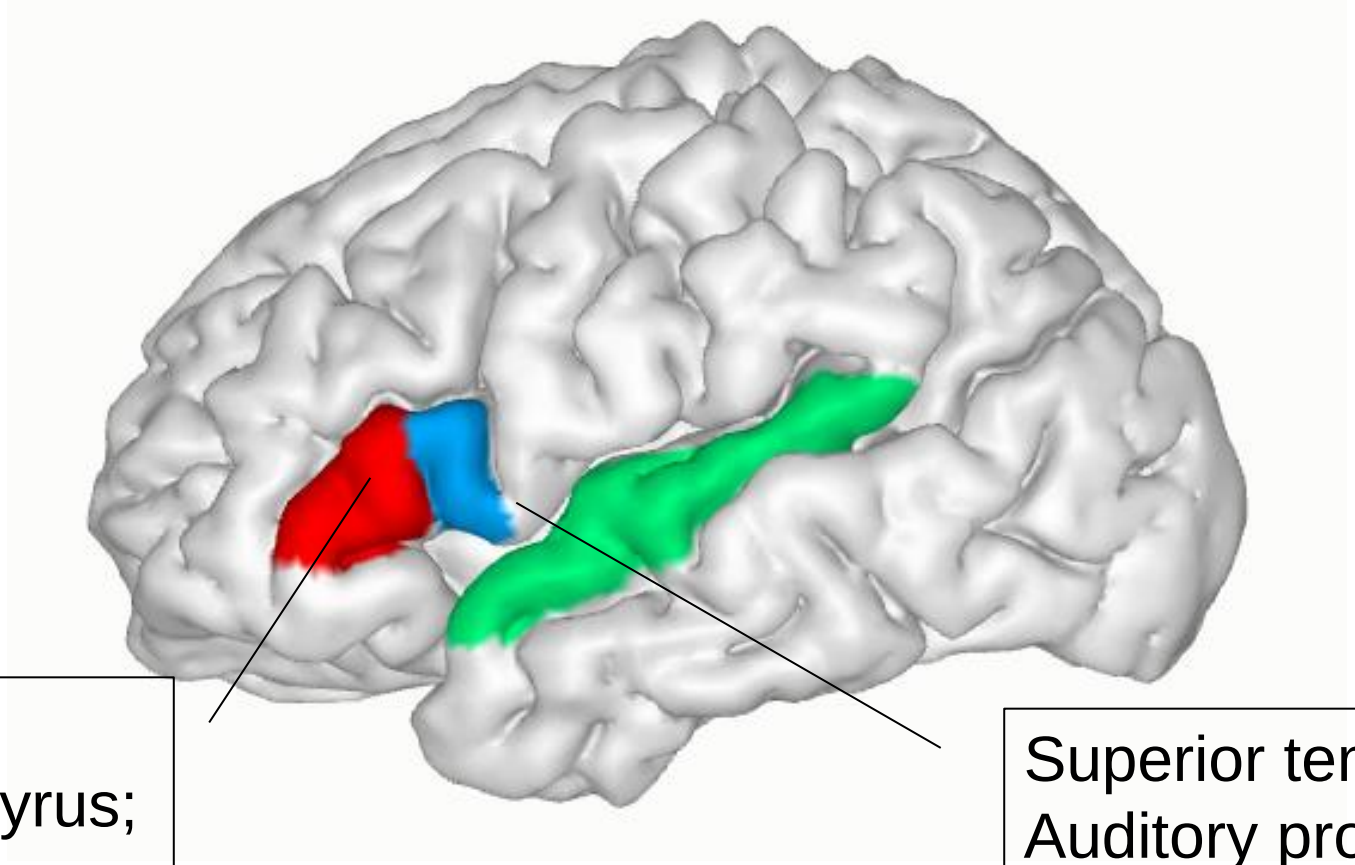
primary auditory cortex

Carl WERNICKE

1874

Brodmann 1909, photos: wikipedia

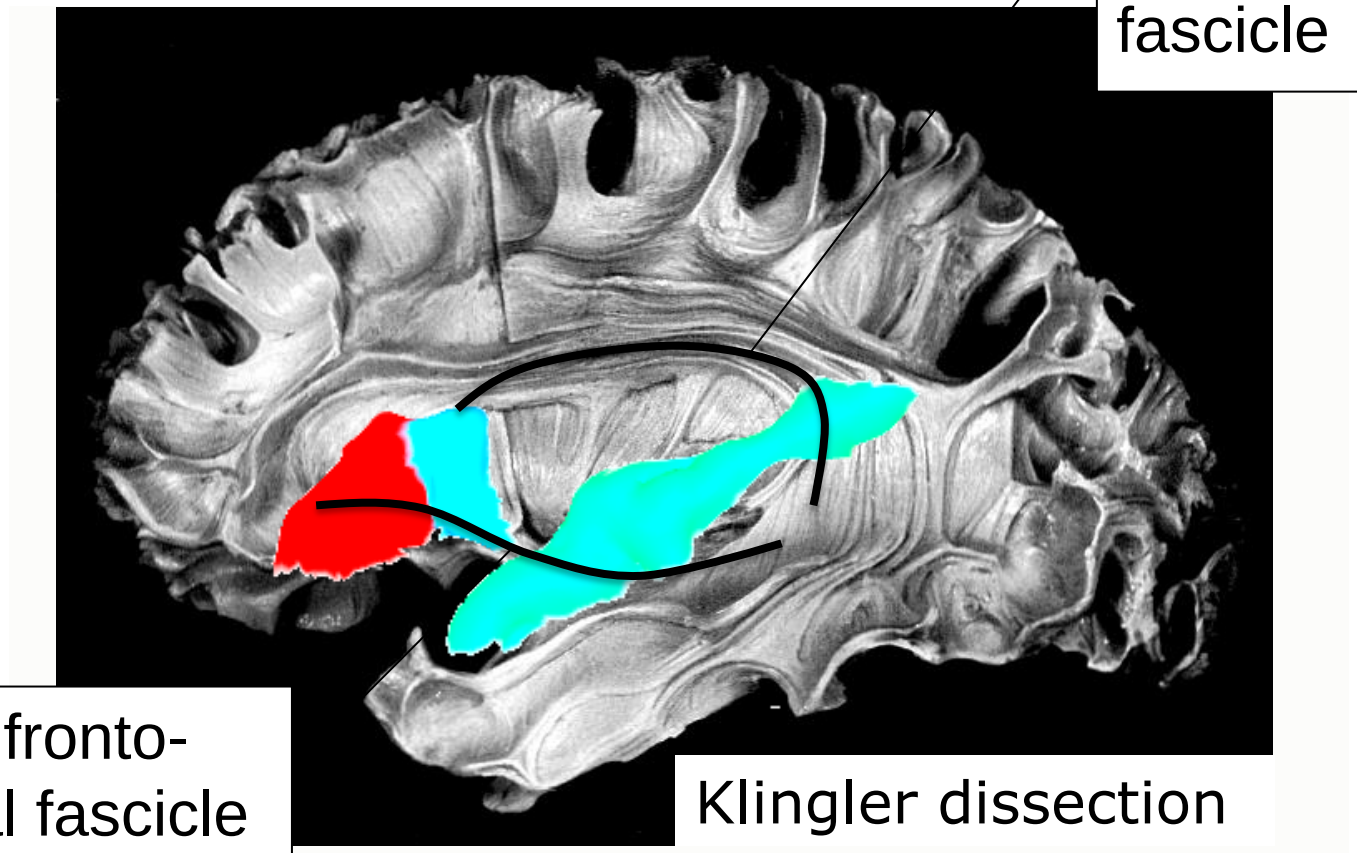
Structural connectivity between the language cortices



Inferior frontal gyrus; Broca‘s area

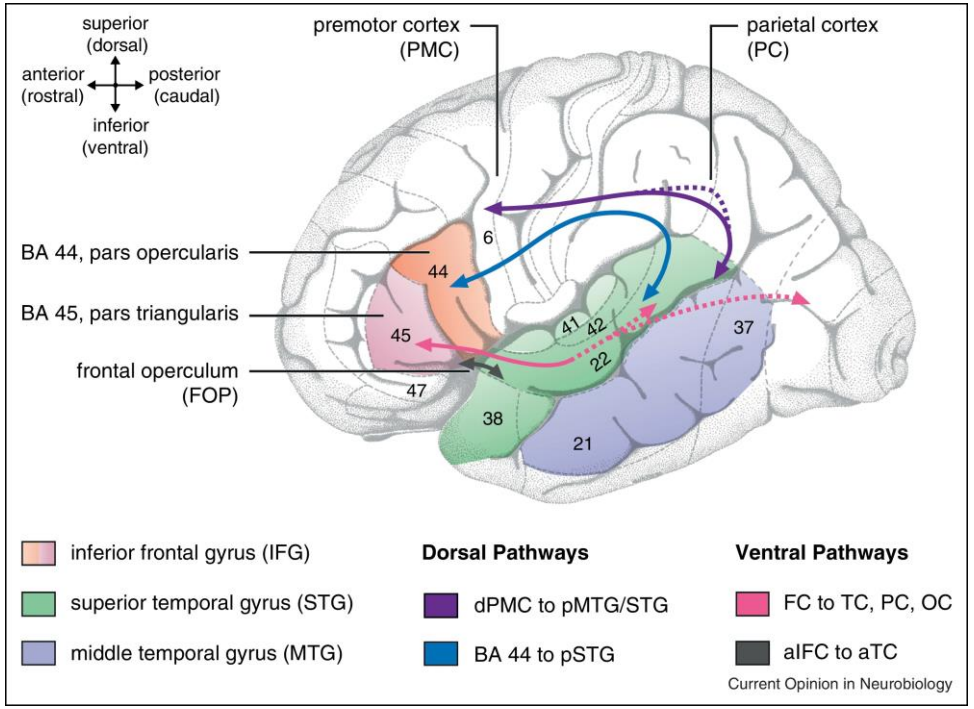
Superior temporal gyrus
Auditory processing

Structural connectivity between the language cortices

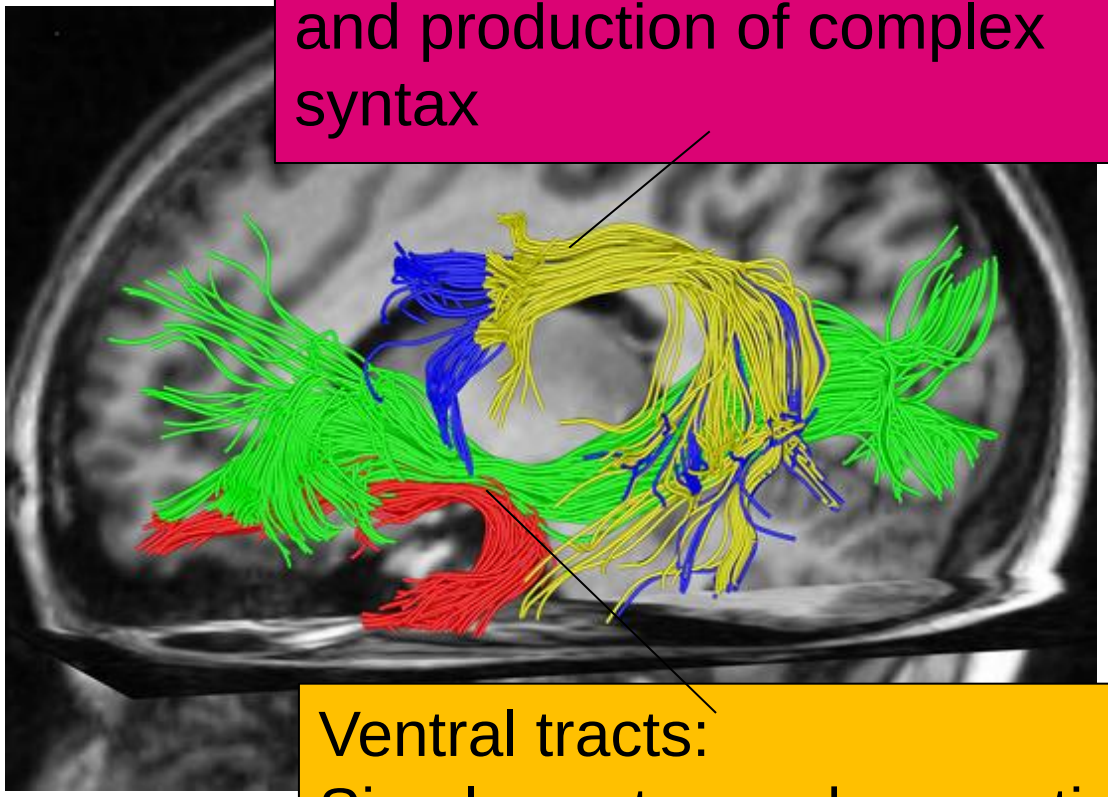


Ludwig, Klingler: Atlas cerebri humani, 1956.

Dorsal and ventral tracts for language



Dorsal tracts: comprehension and production of complex syntax



Ventral tracts:
Simple syntax and semantic processing

Regional Functions:

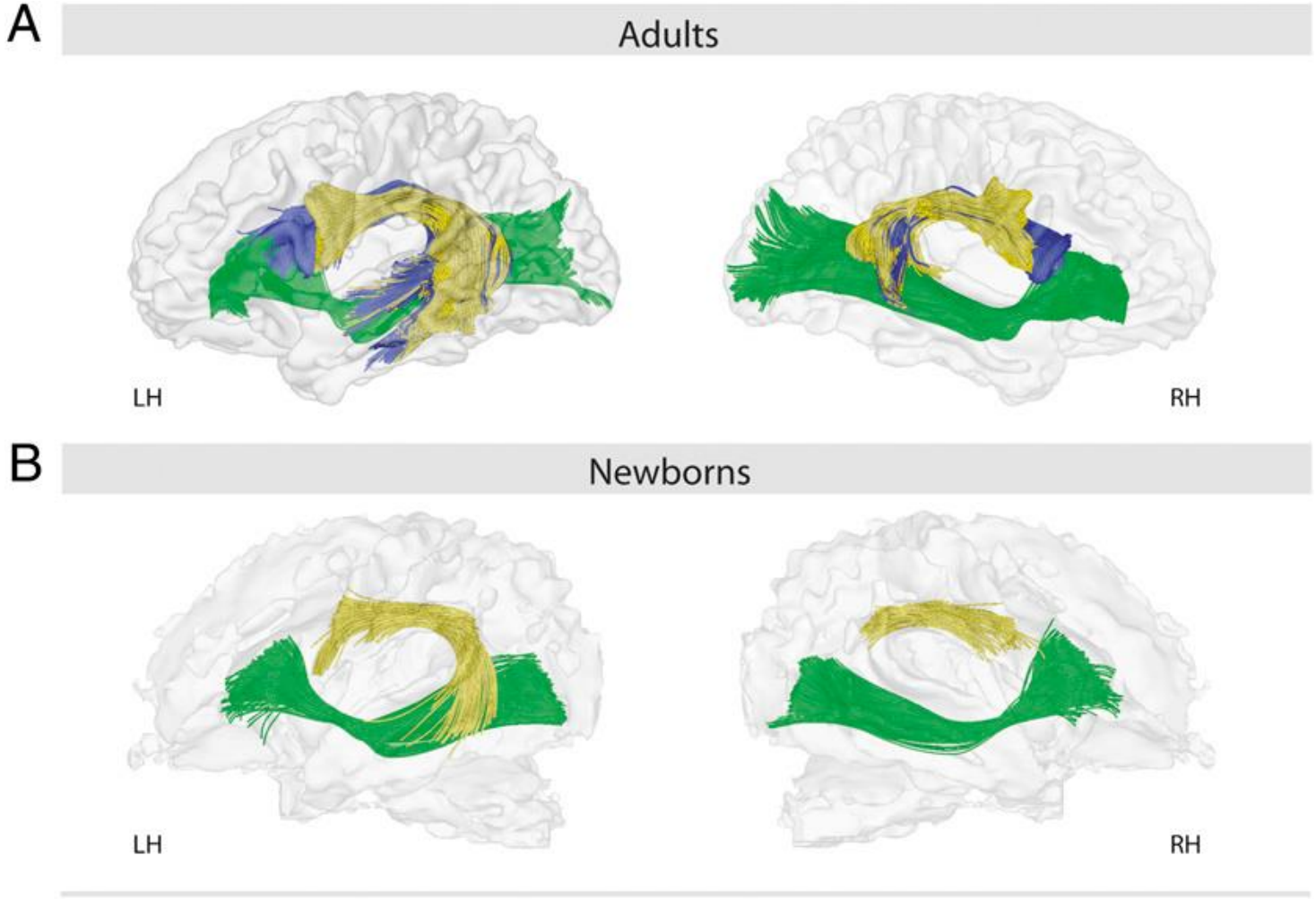
STG/IPL: Phonological processing
MTG: lexical–semantic processing
BA44: Complex syntax processing
BA45: Semantic processing

Pathway :

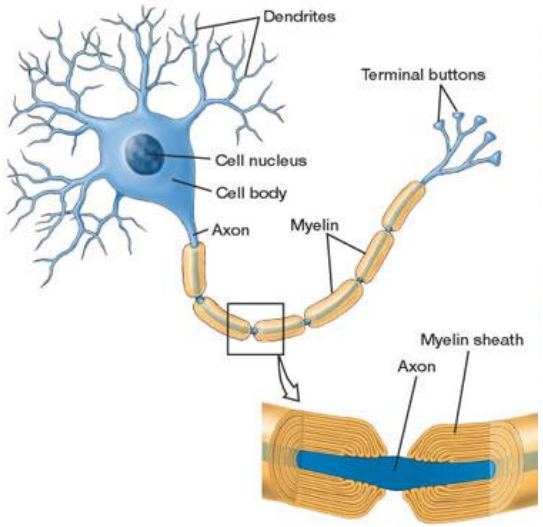
dPMC- STG/IPL: Auditory-motor mapping
BA44- pSTG: Complex syntax processing
aIFG-aTC: Elementary combination
FC-TC,PC,OC : Semantic processing

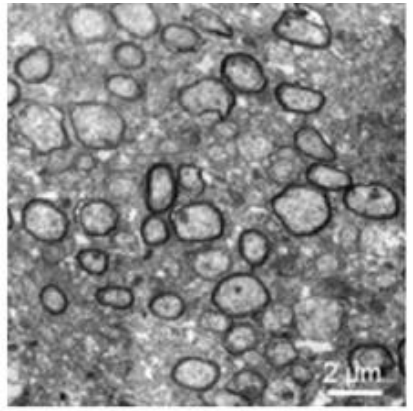
Friederici 2011

Dynamic changes in brain connectivity during development



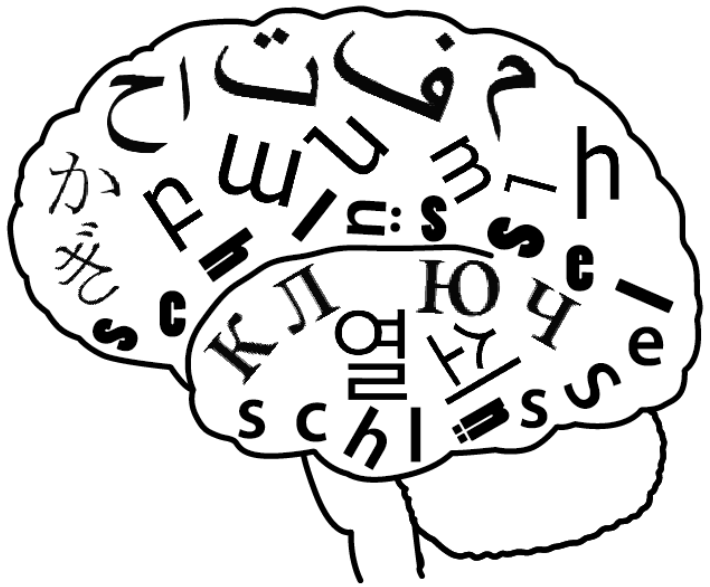
Perani et al. PNAS 2011





- Newborns: weak connections between the language regions
- Myelination starts after birth
- The network of connections is molded from the external world during development

How language shapes the brain:



Cross-linguistic differences in the universal language network

Different languages – Different strategies?

German

Free word order
(verb at the end)

Informative **syntax**

English

Fixed word order

Little syntax

Angela D. Friederici

Mandarin Chinese

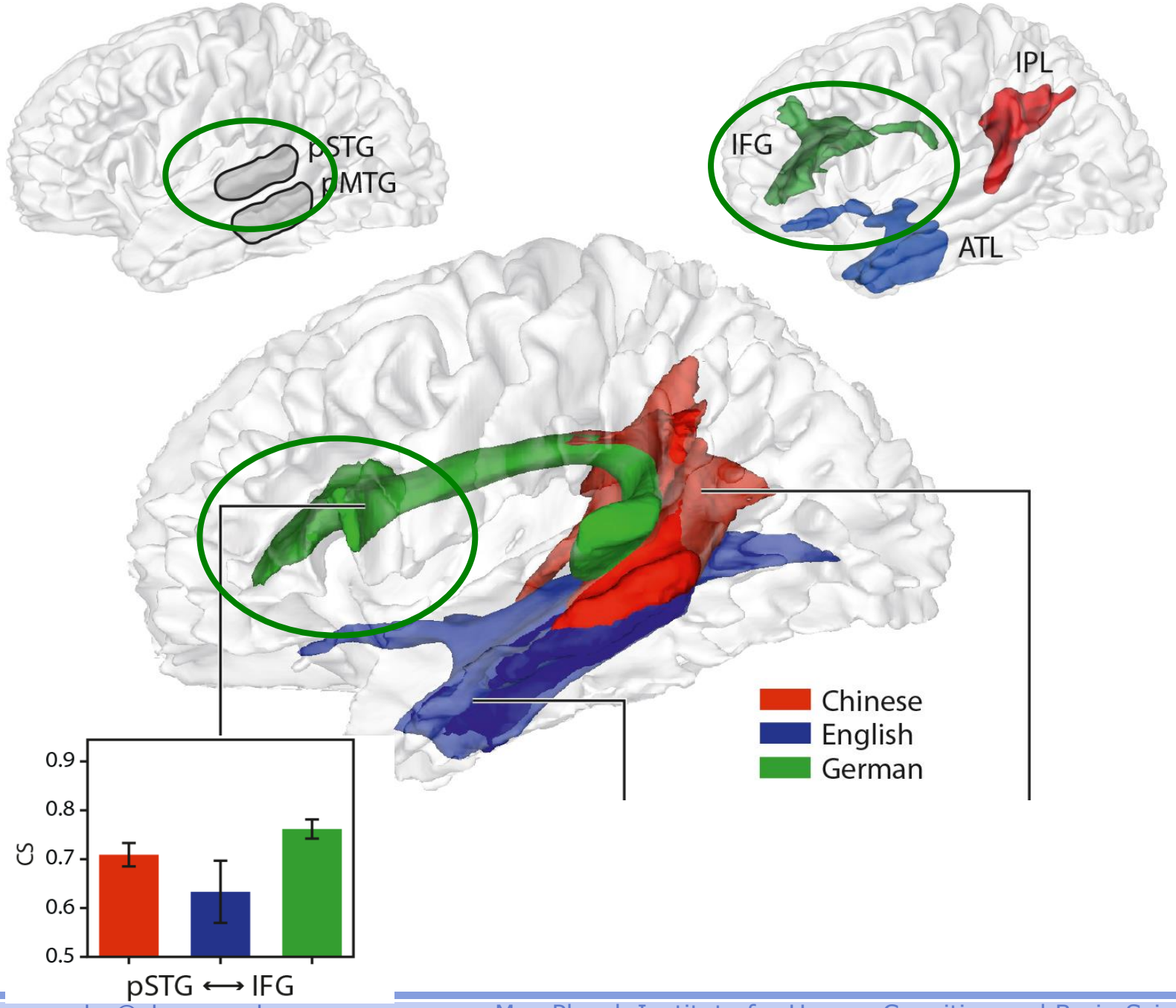
Tonal language

Abundant **homophones**

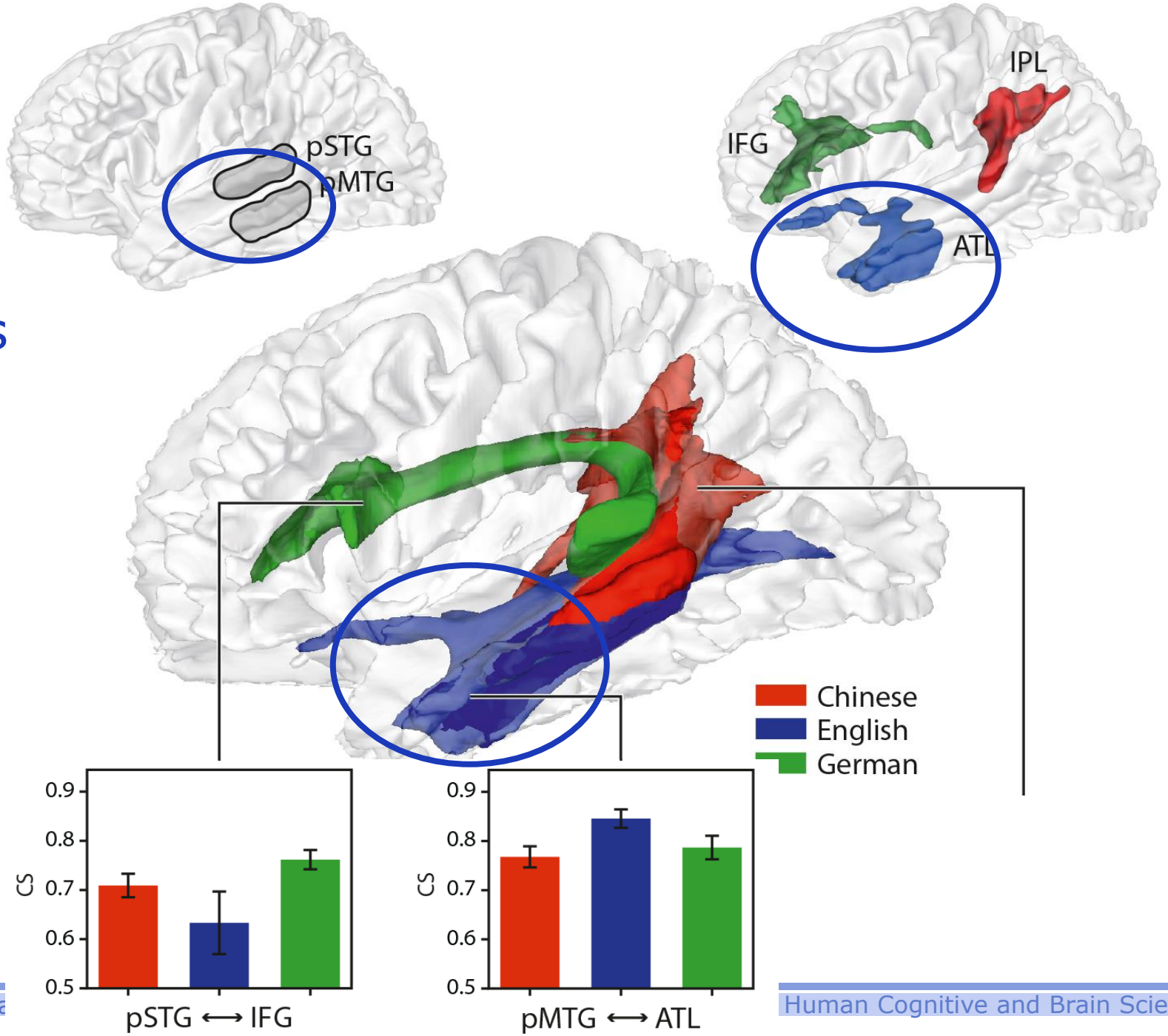
Tomás Goucha

Conjunction across languages

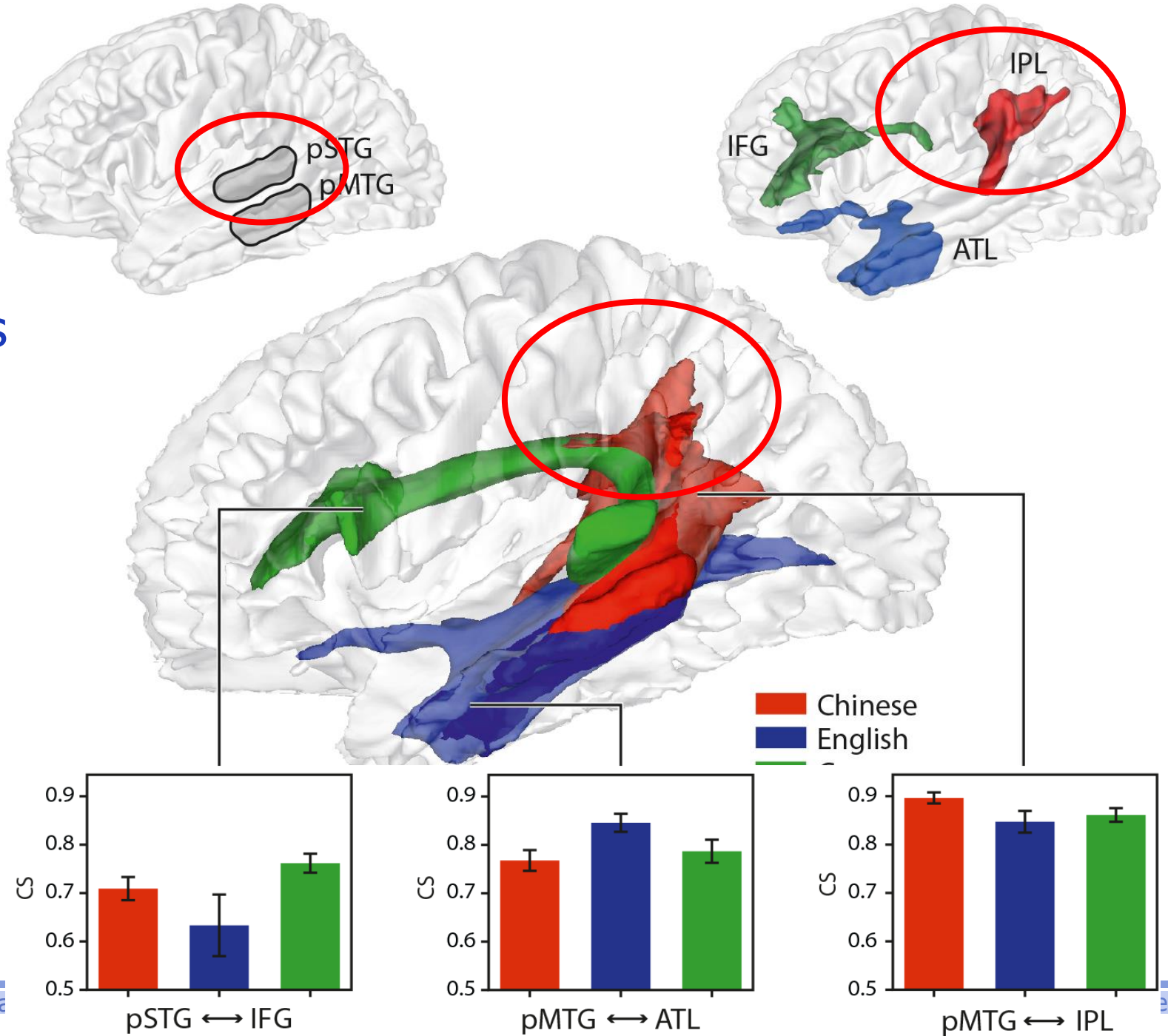
- N=30 German
- N=20 English
- N=30 Chinese
- Matched for: gender, age, handedness, level of education
- Replication second dataset (18+18+18)



Conjunction across languages



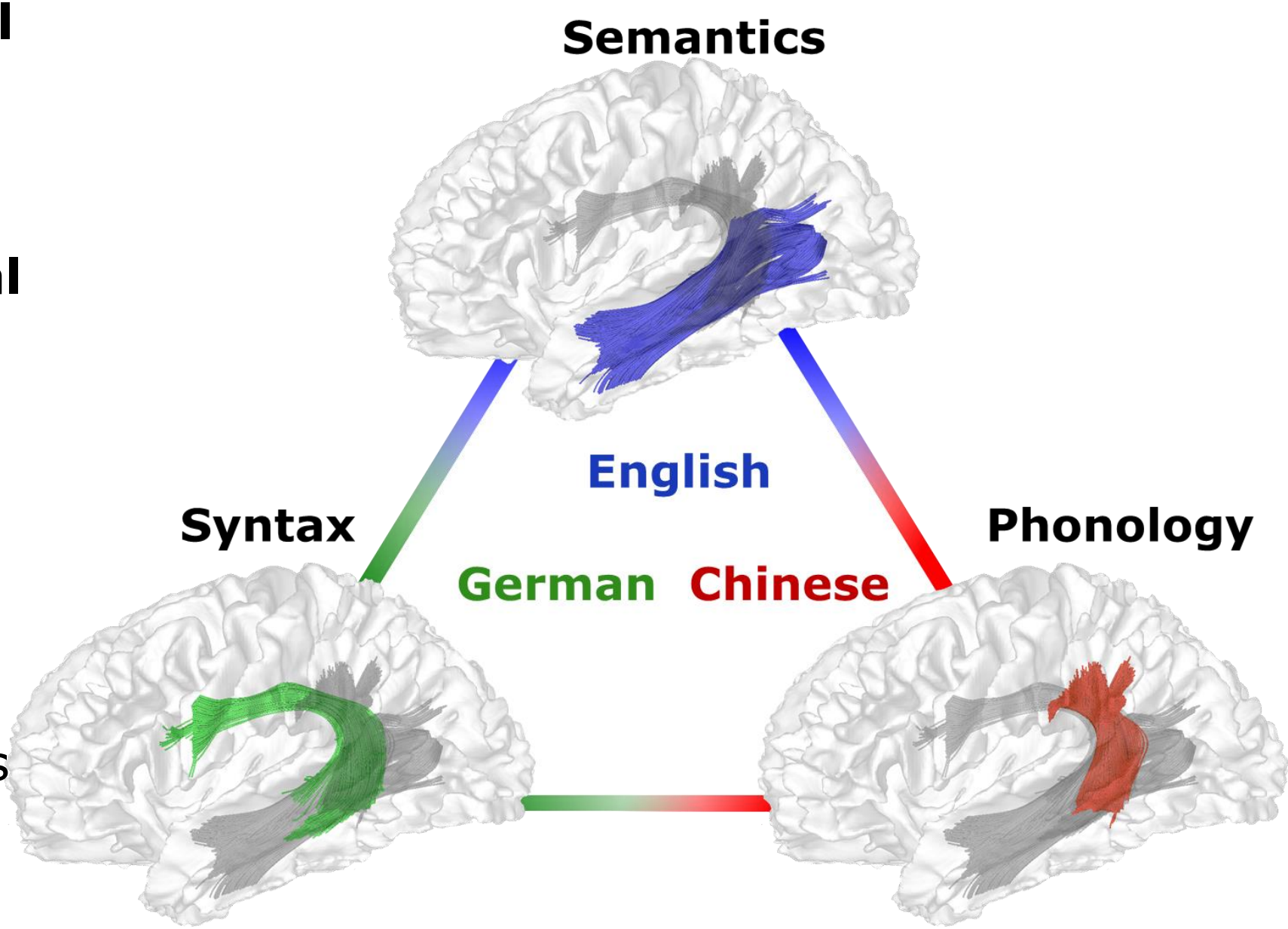
Conjunction across languages



- **German** group –**dorsal** connectivity – **grammatical** cues

- **English** group –**ventral** connectivity – word **meaning** associations

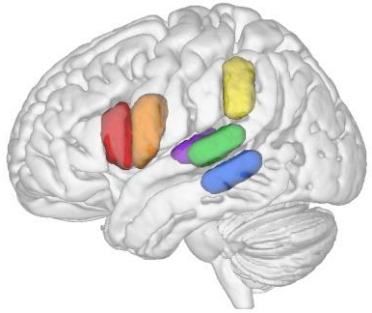
- **Chinese** group – **temporo-parietal** and interhemispheric connectivity – **phonological** demands of tonal language frequent homophones



Language without speech: Language network in prelingually deaf signers

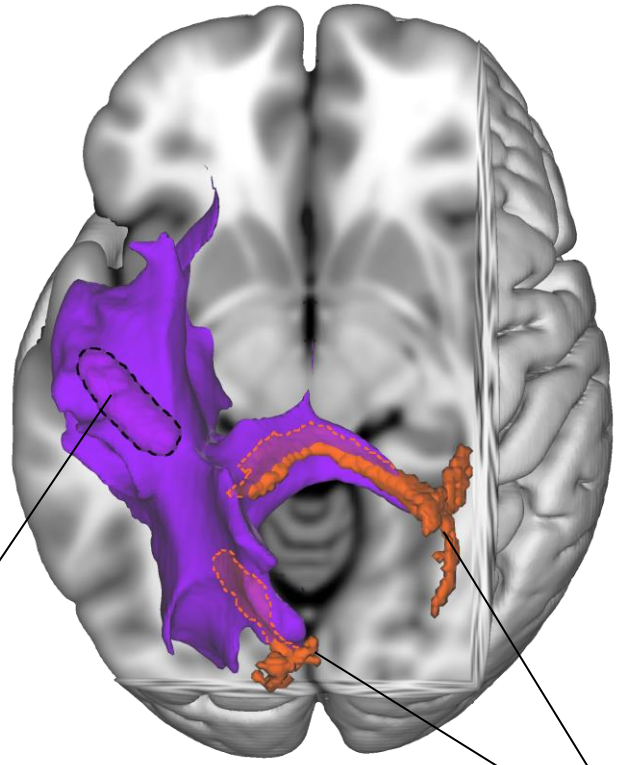
- **Compare connectivity in the dorsal language processing network between signers and controls:**

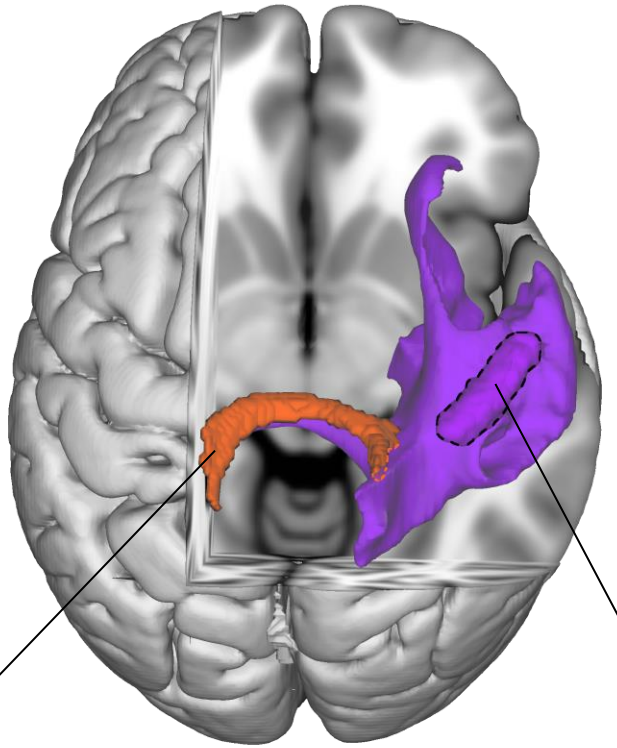
- Is the **language** network affected by missing **auditory input** and missing **speech** production?



Primary Auditory Cortex

- Strongly reduced interhemispheric connectivity in signer
- Left: Reduction in connectivity to precuneus



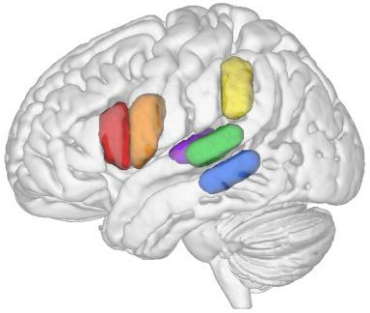


seed ROI
Heschl's gyrus

significant
reduction

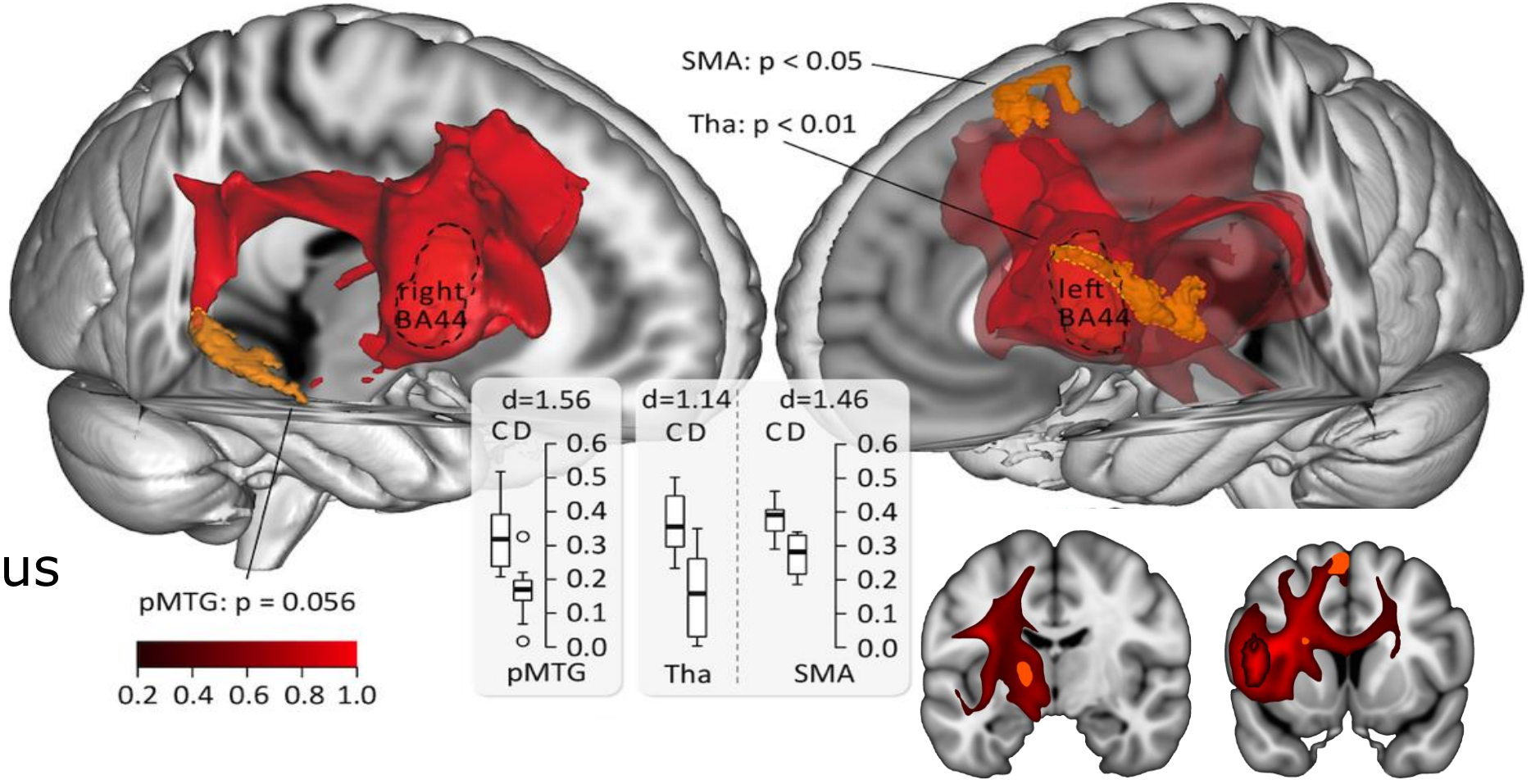
seed ROI

Finkl, et al. Cerebral Cortex 2019.



BA44 - Speech Planning and Syntax

- Left: Reduced connectivity to pre-SMA and thalamus
- Right: Reduced connectivity to MTG/hippocampus
- Arcuate facicle unchanged



Finkl, et al. Cerebral Cortex 2019.

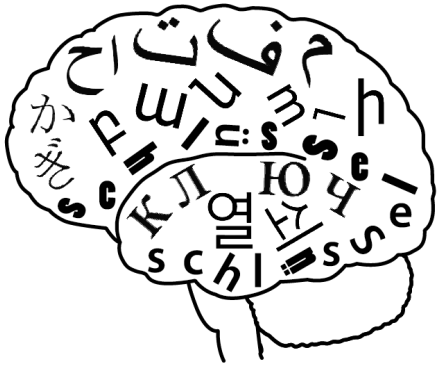
Language without speech

- Signers show normally developed dorsal language network
- Missing auditory input causes **reduced interhemispheric connectivity** of primary auditory cortex
- Missing speech production is linked to a reduced connectivity of BA44 to **pre-SMA** and the **thalamus**

From connections to the connectome

Language network differences between speakers of Arabic and German

Tomás Goucha



Xuehu Wei

German and Arabic language features

German

Free word order
(verb at the end)

Informative **syntax**

Arabic

Root-based langauge with
complex morphology

Word: root (semantic)
+ word-pattern

ROOT

Shape	ب	ت	ك
Symbol	b	t	k
Meaning	write		

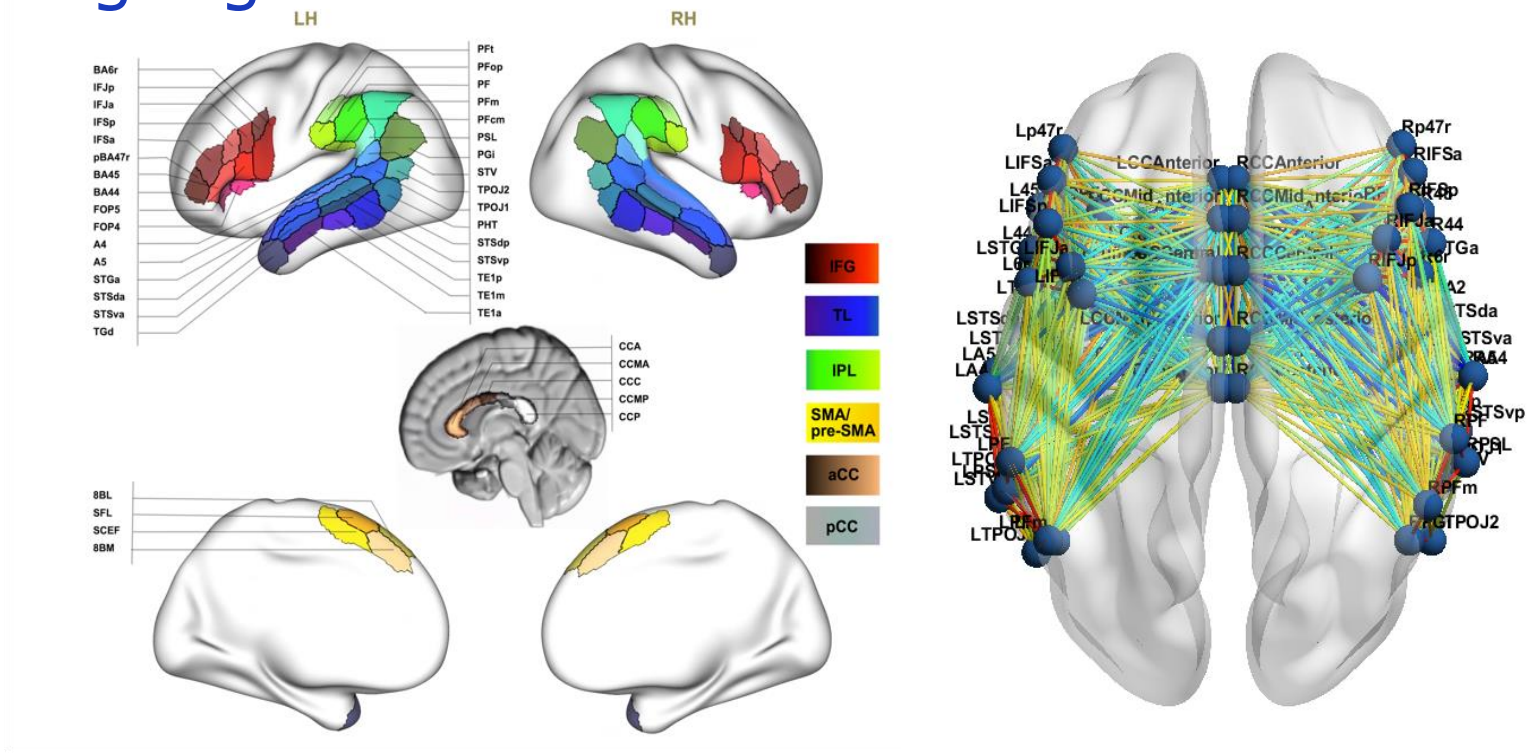
Meaning	Transcription	Arabic
a book	kitaab	كِتاب
a writer	katiib	كاتِب
he writes	yaktab	يَكْتَب
she writes	taktub	تكتب

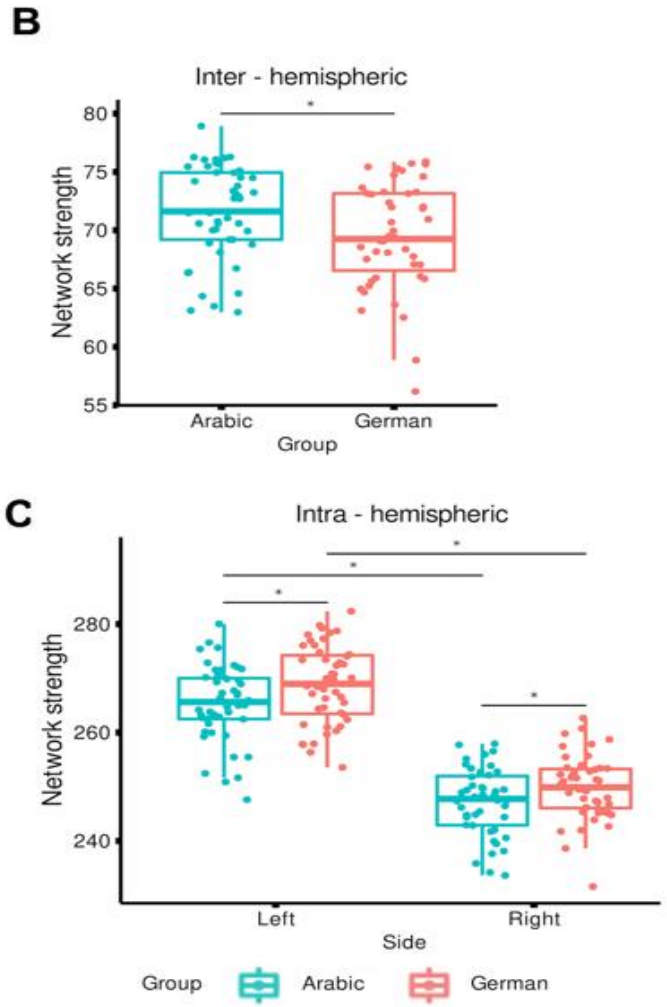
- Missing short vowels in script

Name	Symbol	Diacritical Mark
fatHat	a	ـَ
Dammat	u	ـُ
kasrat	i	ـِ

Taha and Saiegh-Haddad, 2017; Al Kaabi, 2016

Intra- and inter-hemispheric connectivity differences in the language network





47 German and 47 Arabic native speakers

age matched; mean age 26 years

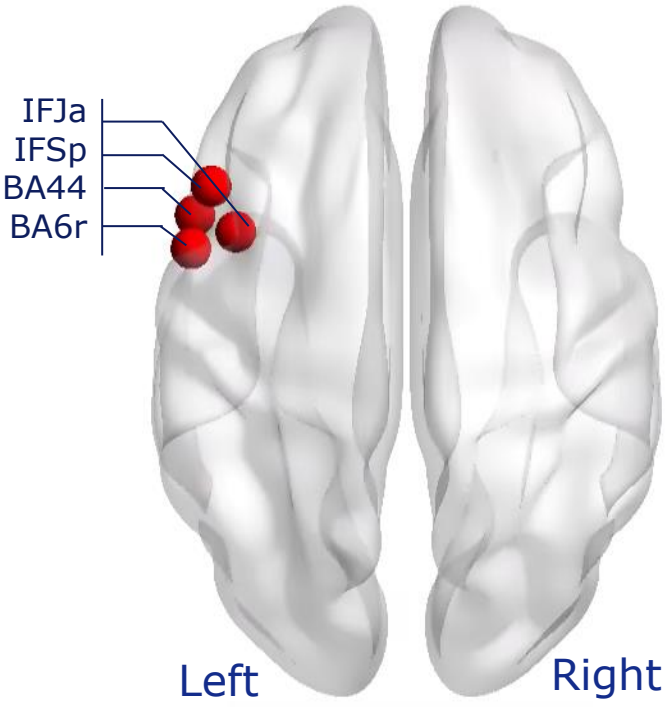
Wei et al. Neuroimage 2023

Differences in connection strength per region

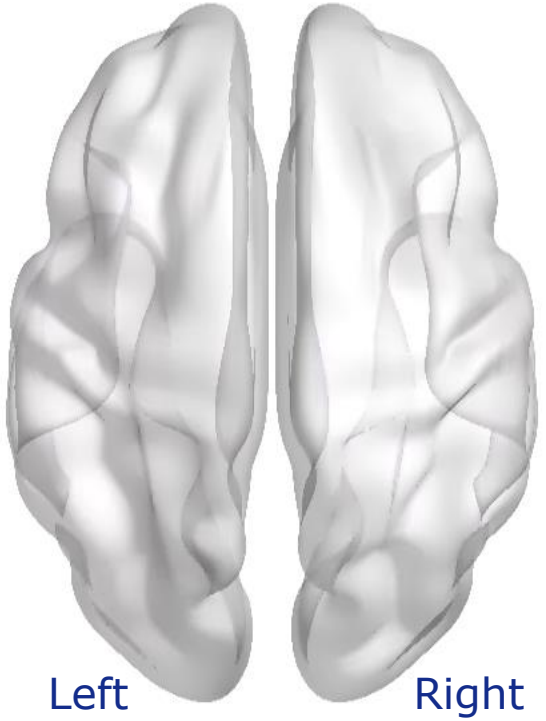
German native speakers show higher centrality than Arabic native speakers in the left IFG

Difference in sub-regions of the IFG

German > Arabic



Arabic>German



No significant higher node centrality in Arabic compared to German native speakers

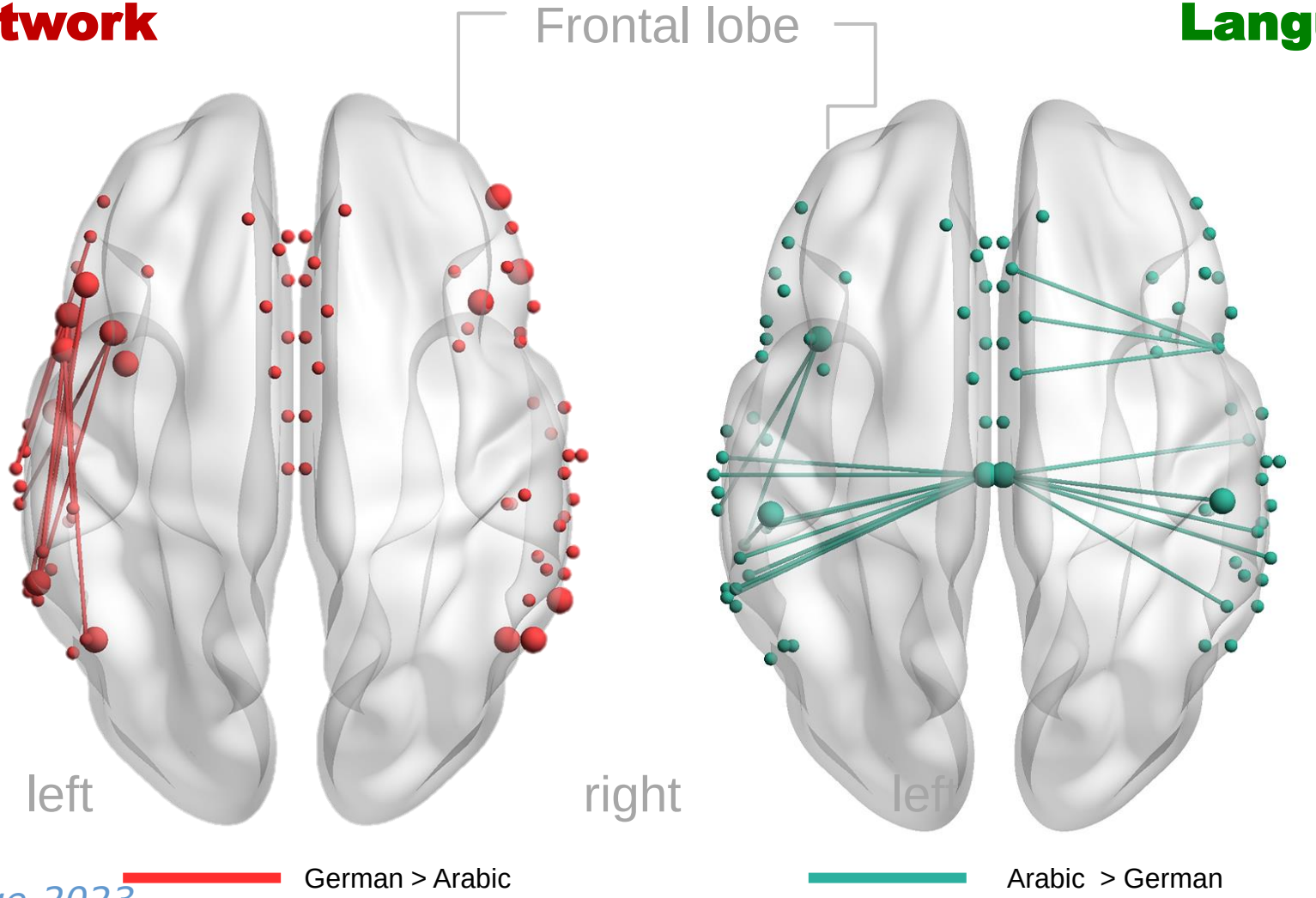
Wei et al. Neuroimage 2023

Differences in connectivity between regions

Specific German Language Network
(top view)

German native speakers:

Stronger connectivity in the left frontal-parietal-temporal language network, associated with complex syntax processing



Specific Arabic Language Network
(top view)

Arabic native speakers:

Stronger inter-hemispheric and left temporo-parietal network connecting semantic language regions related to rich morphological processing in Arabic

Wei et al. Neuroimage 2023

Take home message

- During development, the brain network “hard codes” the (language) experience
- Related to different processing regions an strategies in different languages
- Differences in network properties reflect the neural adaptations
  -> specific linguistic features of a particular language
- Differences in this hardware might also modulate reasoning in other cognitive domains (this network is not only used for language)
- The brain connections, our connectome, reflects parts of our personality

Thank you!

شكراً جزيلاً!

Angela D. Friederici

T. Goucha, H. Adamson

X. Wei, T. Finkl

M. Schwendemann

M. Lisanik,

Department of NPSY

MPI CBS and all

collaborators

and you

for your questions!

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG