



15.03.22 08:42

A cross-brain neural mechanism for human-to- human verbal communication



Hirsch et al., 2018

Overview

- Focus: Interactive Brain Hypothesis
- Methodology: Object Naming & Description
- Core Ideas:
 1. Theoretical background: Dynamic Coupling in IBH for social understanding
 2. Methodological background: fNIRS, fMRI
 3. Research Objectives: Conversation Dynamics in Object Naming Description Task
 4. Experimental design and results

Cognitive Theories

- Internalism (Neurocentralism)
 - CNS as the most appropriate lead to analyse/conceptualise all mental behaviour
 - CNS **development** and **function** almost completely unaffected by social interaction
- Externalism
 - External elements most important in shaping CNS functions and development
 - Cognitive process from a **functional level** heavily influenced-by/dependent-on elements outside the CNS

Interactive Brain Hypothesis

- Theories on the relation between cognitive agent's brain and social understanding
- **Previous work** primarily focuses on detached experimentation of brain functions
 - Commonly, participants **passively** observe the world
 - **Mind-reading**: social understanding based on interpretation of social stimuli and infer intension
- **Interactive Brain Hypothesis** complements Mindreading
 - **Enactive** approach: as participant instead of passive observer
 - **Participatory sense making**: interaction plays central role in social understanding

Interactive Brain Hypothesis

- **Mind-reading**
 - Brain as (more **static**) Input/Output mapping machine
 - Perception → Cognition → Infer Intension → Decision → Action
 - Brain mostly concentrated on **Cognition and Inference**
- **Participatory sense making**
 - Brain **dynamically** developed, interactive experience and skills play enabling roles in both the development and current function of social brain mechanisms
 - Perception → Cognition → Explanation/Development/Function changes - - -> Decision → Action
 - Brain less concentrated on Cognition, but follows flow of interaction (could be outside full control)

IBH: Interaction Dynamics

- **Nonlinear-processing** -> sensorimotor loop: action affects stimuli
- Dynamic coupling: dyads mutually influences each one's actions
- Dynamic States
 - Coordination
 - Breakdown
 - Recovery of Coordination
- Investigation most convenient during **state transitions**

Technologies

- Objective: functional mapping of brain regions, interpreting brain signals to help understand how brain works
 - Most notable applications: BCI, Preparation for Brain (Tumour) Resection
 - fMRI vs fNIRS
 - fMRI provide insights into relative changes in OxyHb/deOxyHb in regions through magnetic field changes
 - fNIRS uses infra-red and UV light to penetrate tissue, allow primary oxygen carrying Hb, Mb concentration to be visualised and changes measured
 - ! Oxygenation level correlates to a certain degree to intensity of brain activity, but not 100%

Technologies

fMRI (Magnetic)

fNIRS (Infrared)

EEG (Electric)

Non-invasive + Repeatable

Non-invasive + Repeatable

Non-invasive + Repeatable

Strong facial motor interference

Less facial motor interference

some facial motor interference

Slow scans: Less temporal res.

Comparable to fMRI, if not better*

Superior temporal res.

Superior spatial res.
1.5mm x 1.5mm

Marginally* better than EEG

Less spatial res.
2-5cm

Not portable, very restrictive

Portable / Less restriction on head

Portable / Less restriction on head

No movement

Limited movement

Limited movement

Very noisy scanner

less noise

less noise

Full anatomic info

No anatomical information

No anatomical information

Whole brain measurement

Very limited regions and surface

Limited regions and surface

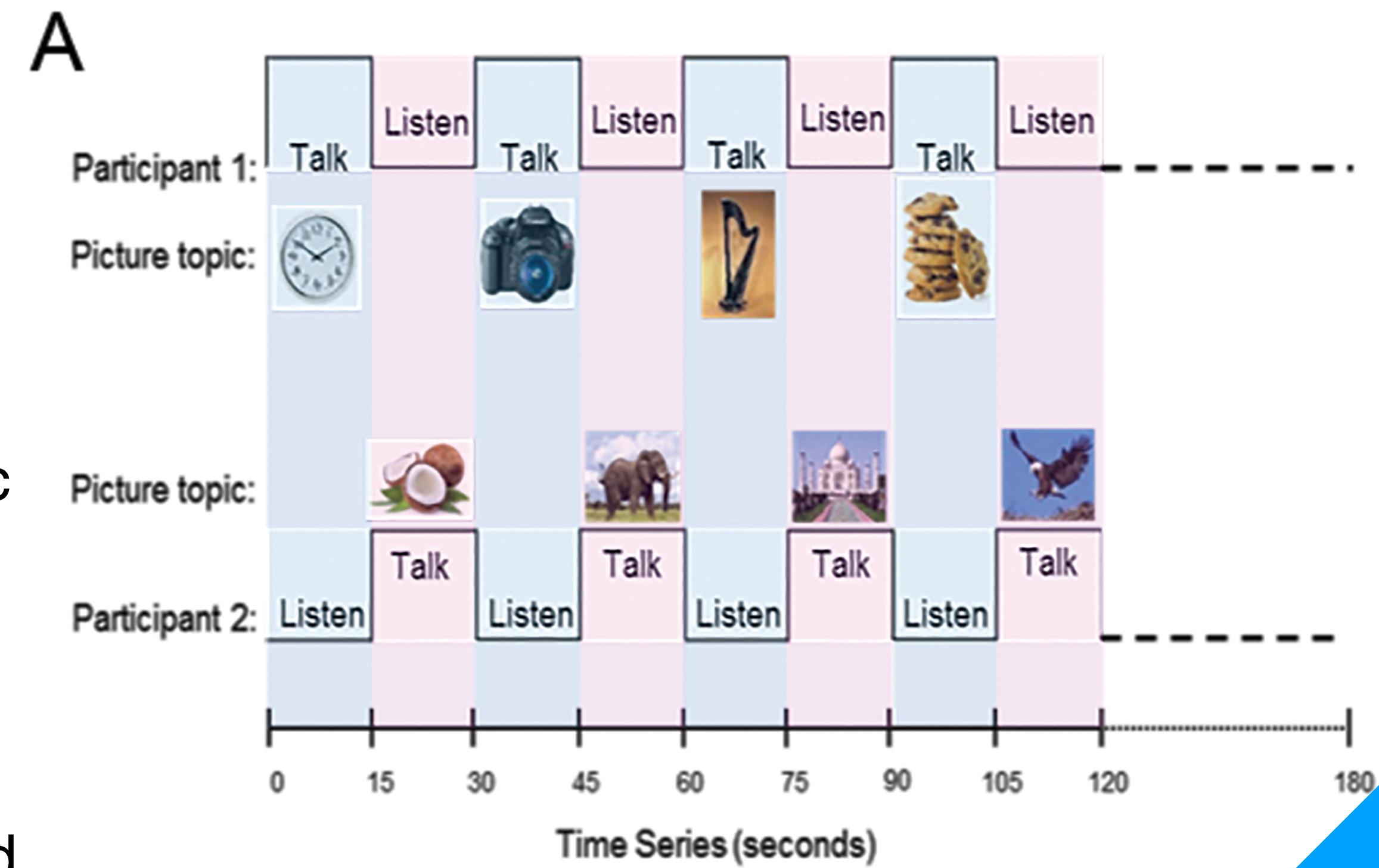


Motivation

- Understanding how the brain mediate dynamic exchanges of information during live verbal interactions
- Brain activity with Intent to communicate
 - during live speaking and listening;
 - with intent to coordinate and recover coordination;
 - is not conventionally differentiated from during static language functions
- Mutual Information Transferring: theorised to require dedicated neural adaptations
- Overt speech: previous experiment primarily monitors covert speech, inconvenient for communication

Task: Object Naming and Description

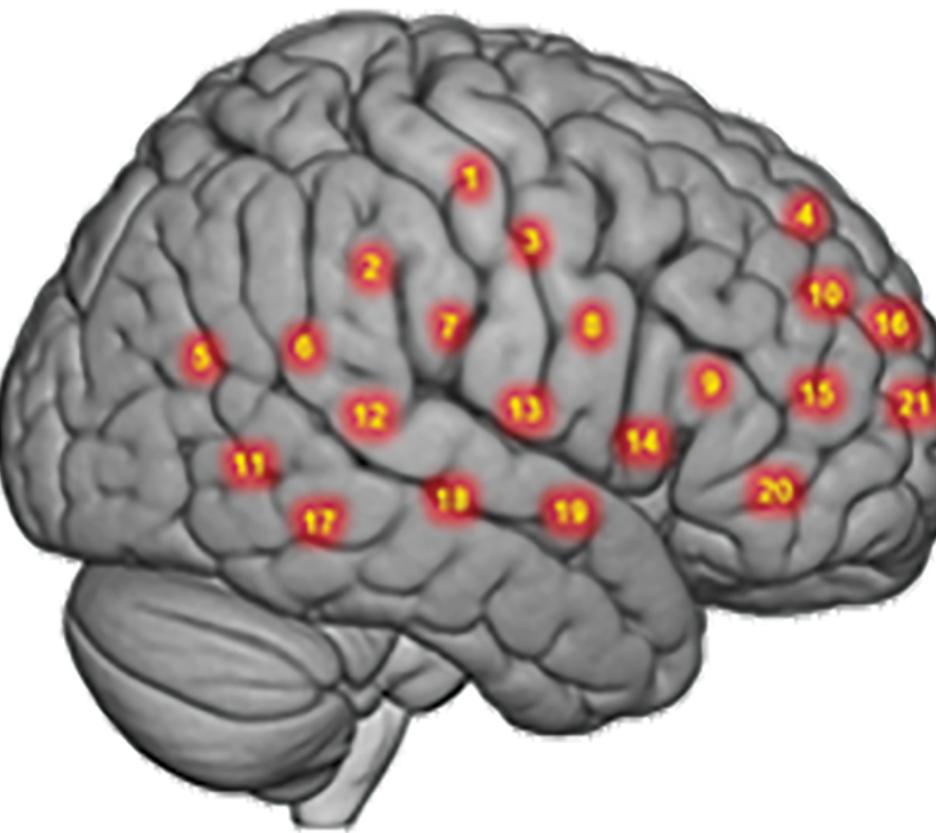
- Control: monologue, speaker named and describe the image
- Two participants
 - Visual: monitors displaying same image
 - Speaker / Listener role switches every 15sec
 - Respond to previous speaker before describing new image
- Video and audio recordings were also acquired for compliance verification



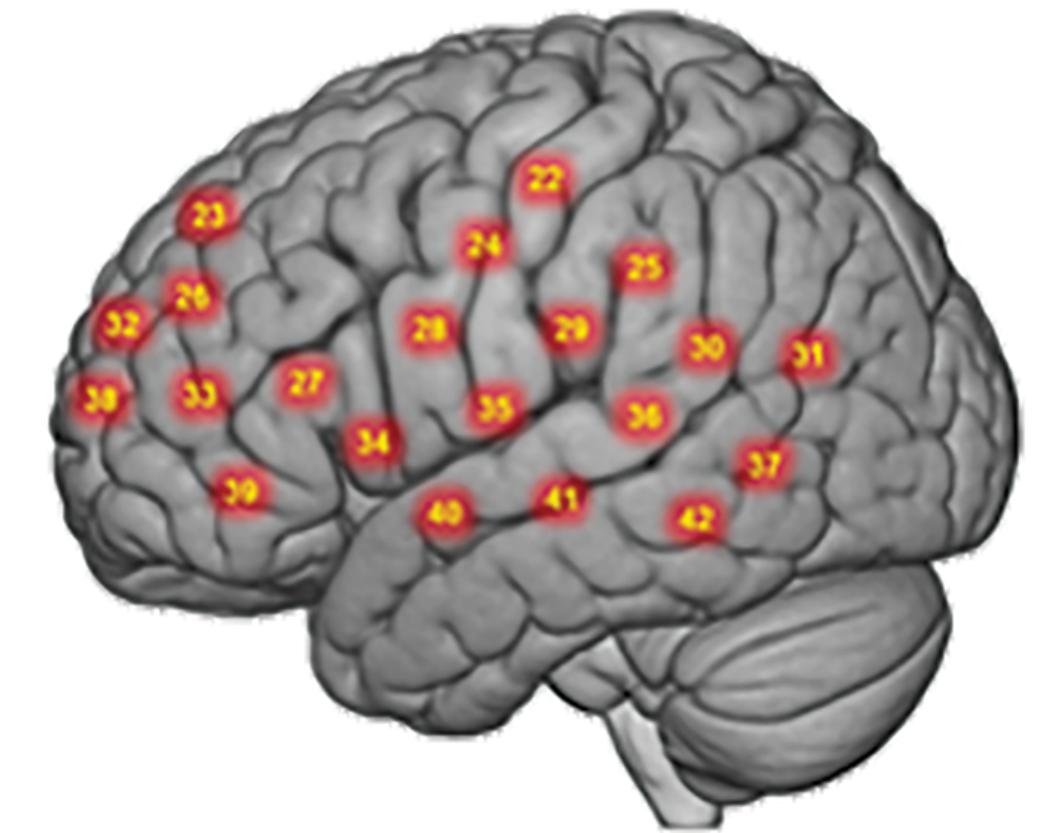
fNIRS setup

- Channel: 42, separation 2.75-3cm
- Temporal res: 27ms
- Measurements:
 - Concentration changes for OxyHb, deOxyHb, and combined deOxyHb/OxyHb
- Anatomical locations: based on head landmarks + linear transformation

Channel layout



Right
hemisphere



Left
hemisphere

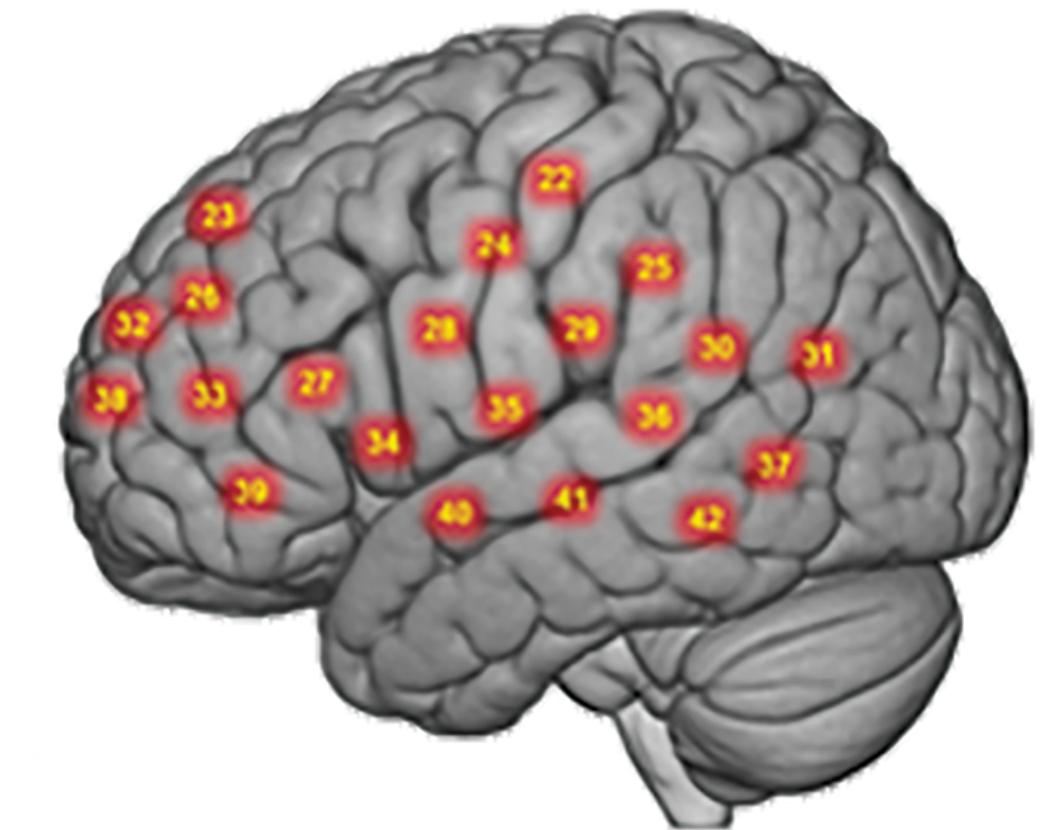
fNIRS setup

- Frontal
 - premotor and supplementary motor cortex (BA6)
 - angular gyrus
 - dorsolateral prefrontal cortex (BA9)
 - dorsolateral prefrontal cortex (BA46)
 - pars triangularis (BA45) (Borca's, speech production)
 - frontopolar cortex (BA10)
- Parietal
 - supramarginal gyrus (BA40)
 - somatosensory cortex (BA1, 2 and 3)
 - subcentral area (SCA) (BA43)
- Temporal
 - fusiform gyrus (BA37)
 - middle temporal gyrus (BA21)
 - superior temporal gyrus (STG) (BA22) (Wernicke's, comprehension)

Channel layout



Right
hemisphere



Left
hemisphere

Technique

Predictions

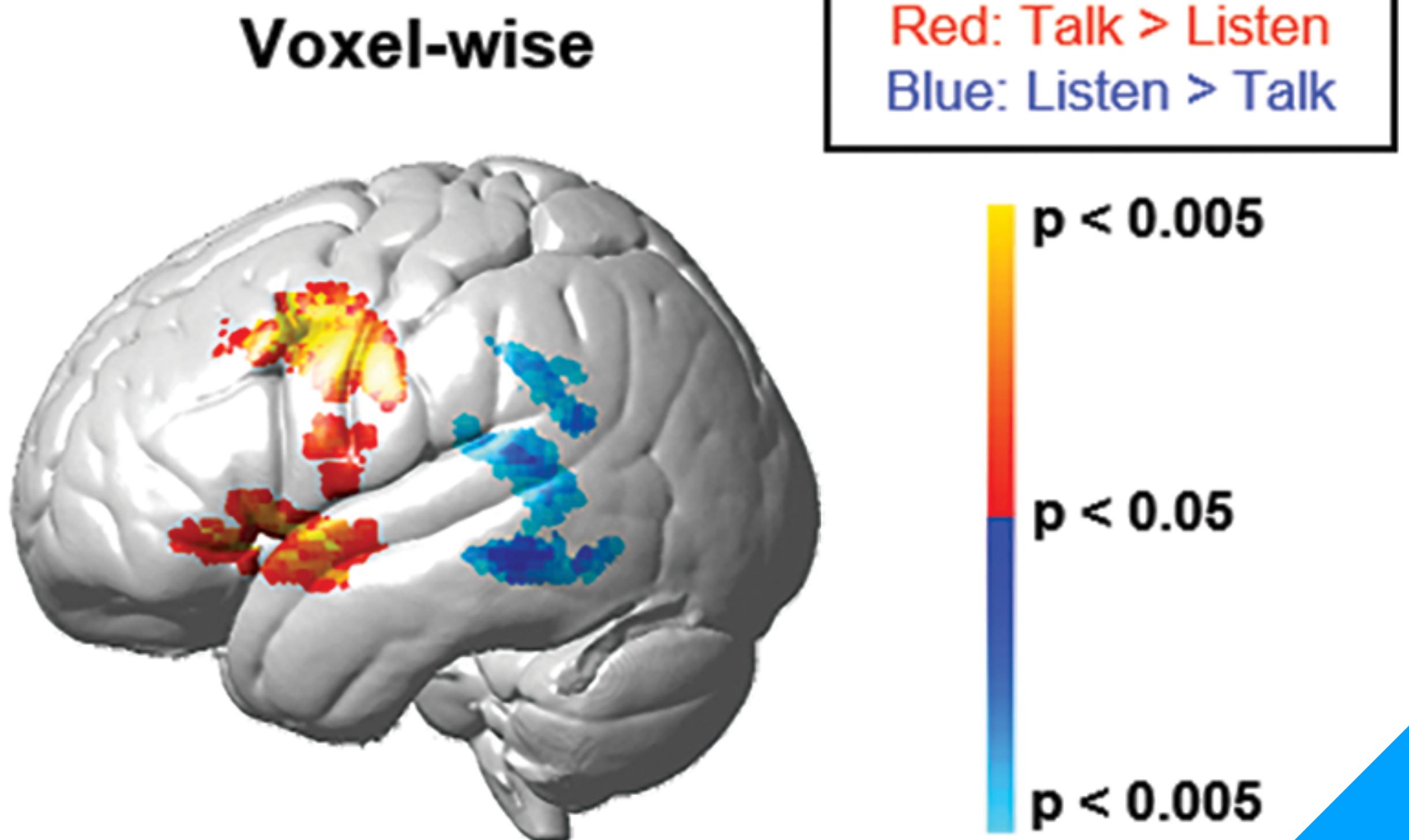
- Increase in within-brain neural activity
 - for regions classically associated with language-related functions; and
 - increases in cross-brain coherence during live interactions involving dynamic speaking and listening for actual partners
 - no significant cross-brain coherence for scrambled persons (not actual partners)

Participants

- 54 healthy adults, 27 pairs, no extensive previous acquaintance
 - 18-42 year's old, mean 24; 12 pairs of mixed gender, 10F, 5M
 - Excluded excessive head movement
 - 4 more for Mono condition (n=58)
 - Screening tasks (with fNIRS), excluded ones without correlated Hb signals in corresponding areas
 - right-handed finger-thumb-tapping task (left motor hand area)
 - passive viewing of a reversing checkerboard (occipital lobe)

ROI Selection (Both cond') (Left Hemisphere Only)

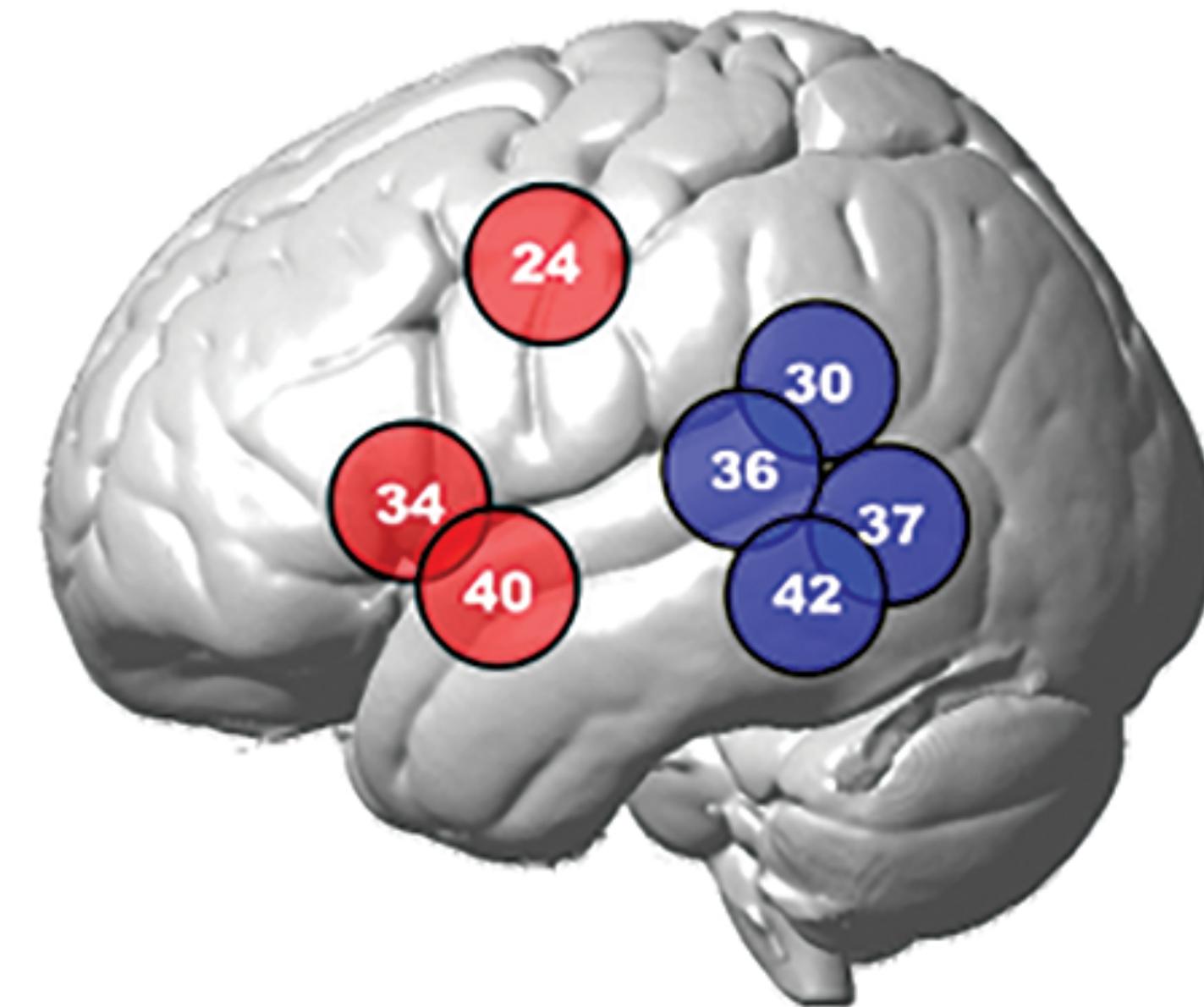
- Voxel-wise contrast between talking-listening
 - Interpolation across participants spatial res. of 2x2mm per voxel
- Observation¹:
 - Include canonical regions for production and comprehension



ROI Selection (Both cond') (Left Hemisphere Only)

- Channel-wise contrast between talking-listening
- direct conversion to MNI, registered to median using interpolation
- Observation¹:
 - Include canonical regions for production and comprehension

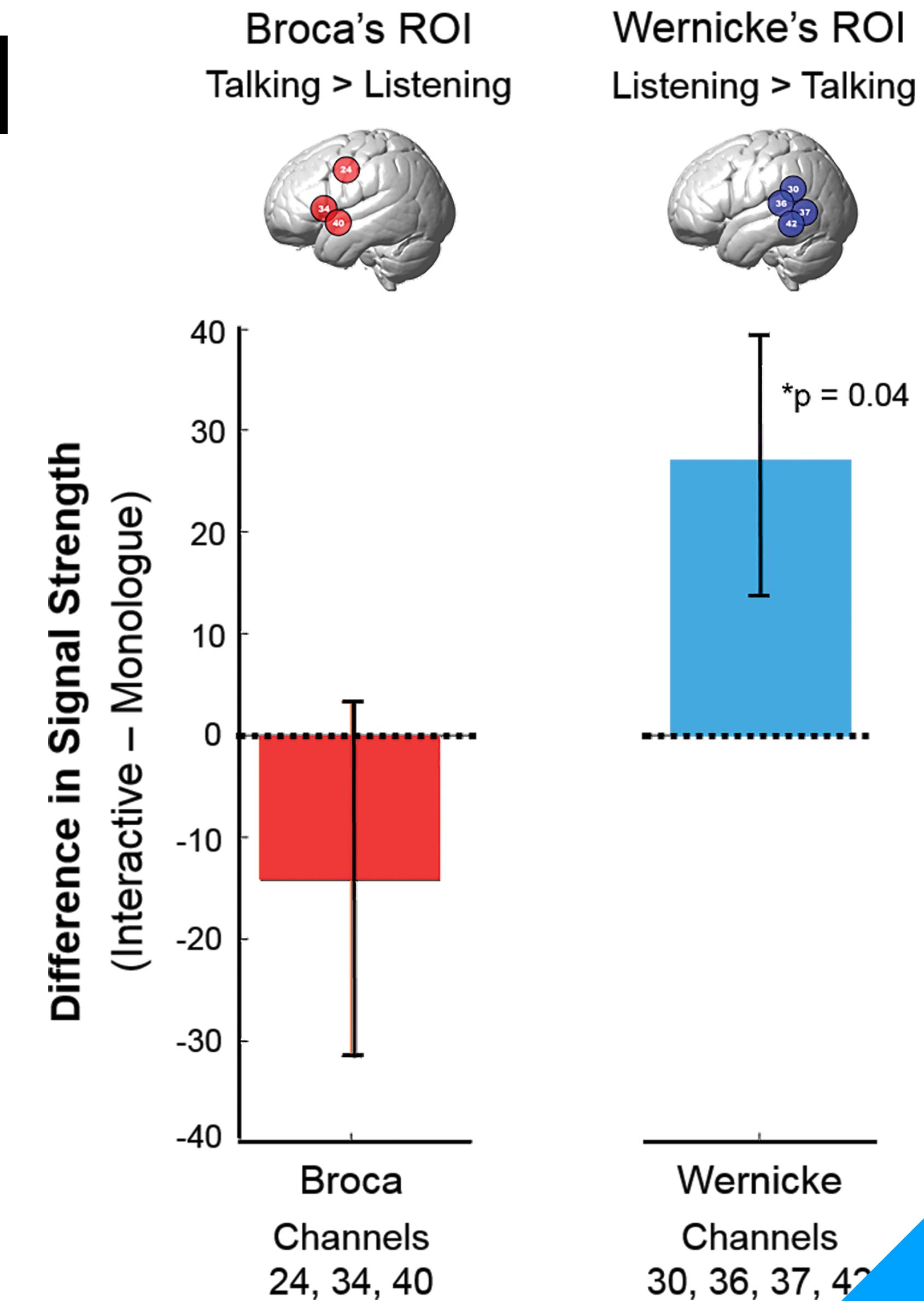
Channel-wise



Red: Talk > Listen
Blue: Listen > Talk

Comparison of Avg. Sig. Diff. for ROI

- Horizontal 0 value avg. of Mono. and Interact.
- Left: Speech Production (Broca)
Interactive less than Monologue $P > 0.04$
- Right: Speech Comprehension (Wernicke)
Interactive more than Monologue, $P < 0.04$



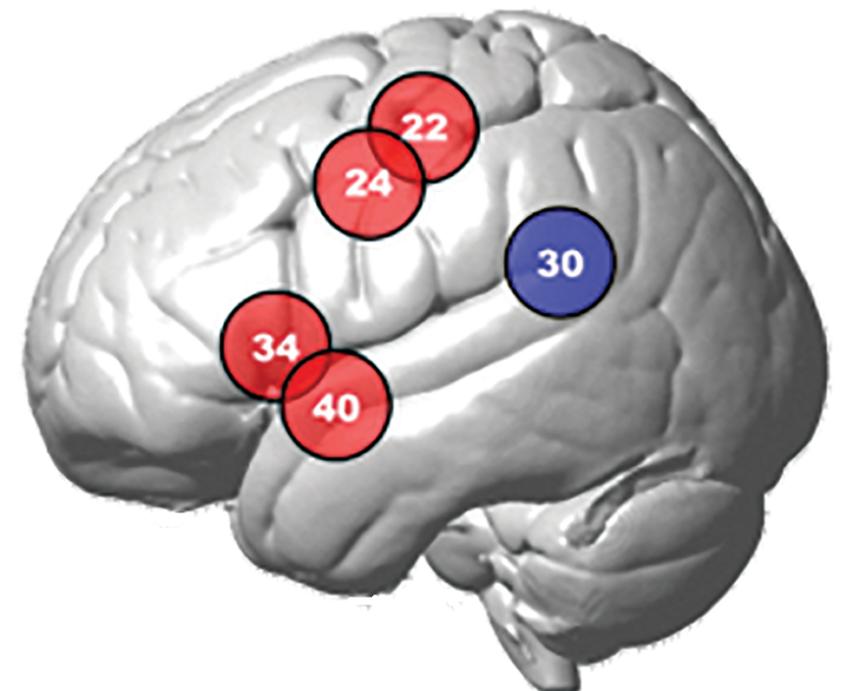
Cluster sizes for ROI

- Comprehension
 - Mono: 1 channel
 - Interact: 5 channels
- Production
 - Mono: 4 channels
 - Interact: 2 channels
- Wernicke's: more responsive to interactive

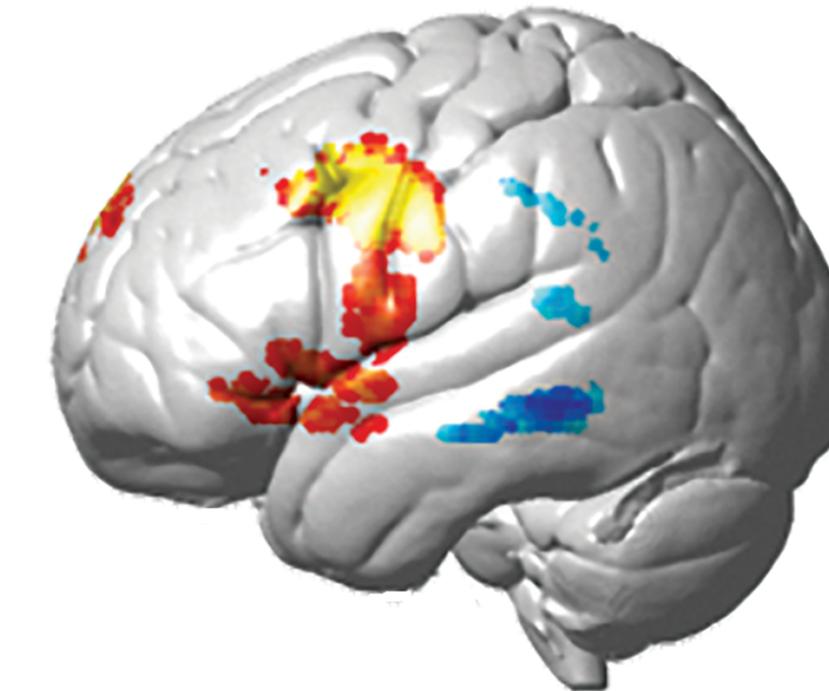
A

Monologue

Channel-wise



Voxel-wise

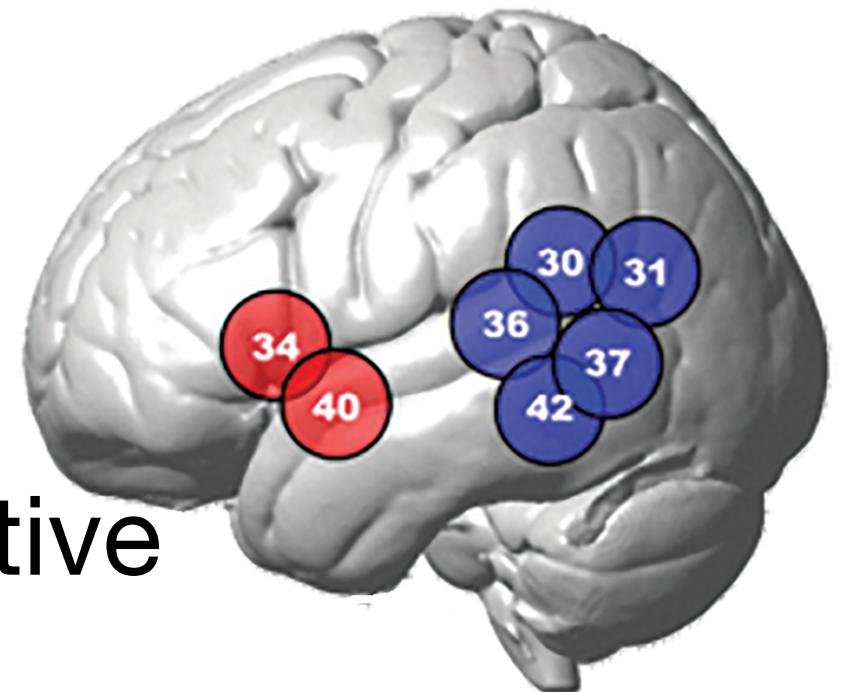


Red: Talk > Listen
Blue: Listen > Talk

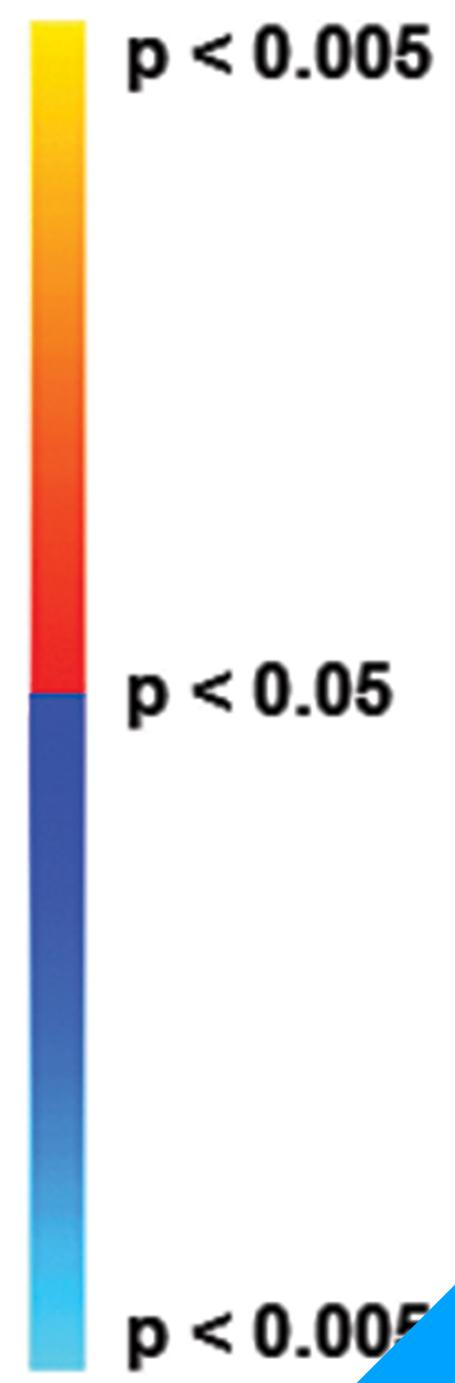
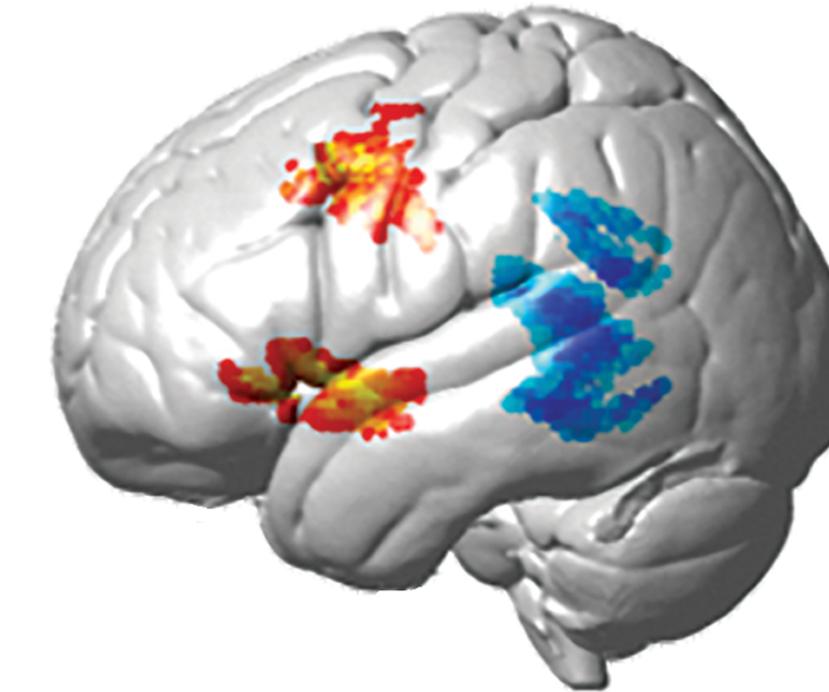
B

Interactive

Channel-wise



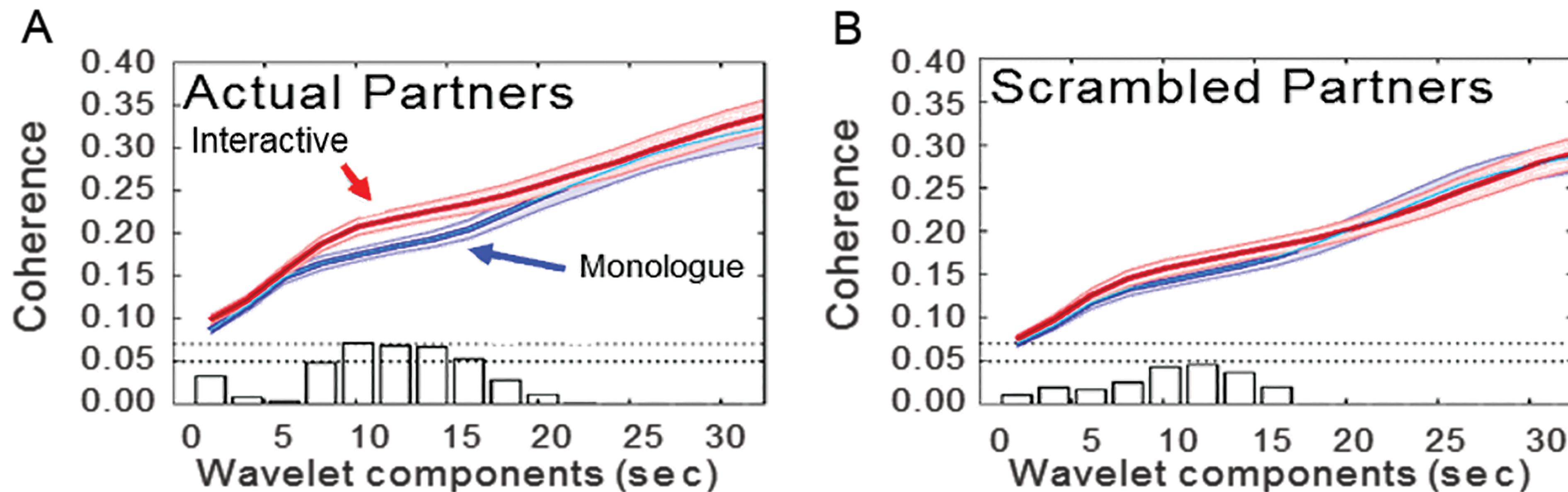
Voxel-wise



Data

Cross-Brain Coherence

Superior Temporal Gyrus (STG) and Subcentral Area (SCA)



- STA and STG Increased crossbrain coherence in interactive
 - STG of Brain 1 coupled with SCA of Brain 2 and v.v.
- A: Cross-brain coherence greater for the interactive (red) than the monologue (blue) for actual partners
- B: Cross-brain coherence no difference for scrambled partners randomly paired with person from other pairs

Contrast and Coherence

- Wernicke's area
 - Interactive: increased contrast-based neural activity, as do cross-brain coherence
- Broca's area
 - not statistically significant difference in Voxel- nor Channel-based analysis
- Cross-brain coherence¹ (STG with SCA) -> Indicator for dynamic coupling for exchanging information (SCA is not a canonical language region)
 - SCA: might have functional role for social content
 - Dynamic coupling: potential social info share between participants (sender, receiver even)

1. consistent with previous expt. involving eye-to-eye contact in mutual gaze task