Instructor-learner brain coupling discriminates between Instructional approaches and predicts learning

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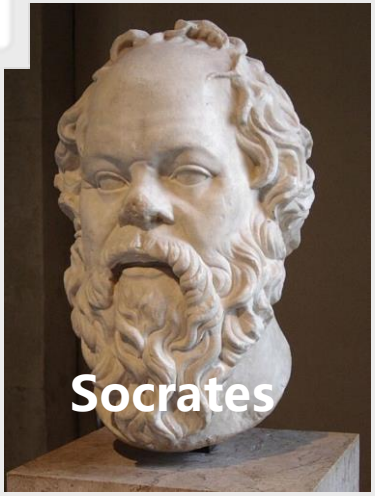
Socratic dialog

Please go across the field and pick one most beautiful flower. P.S. No going back. Only once.

Is this the most beautiful one?

This is happiness.



What is happiness?

How about this?

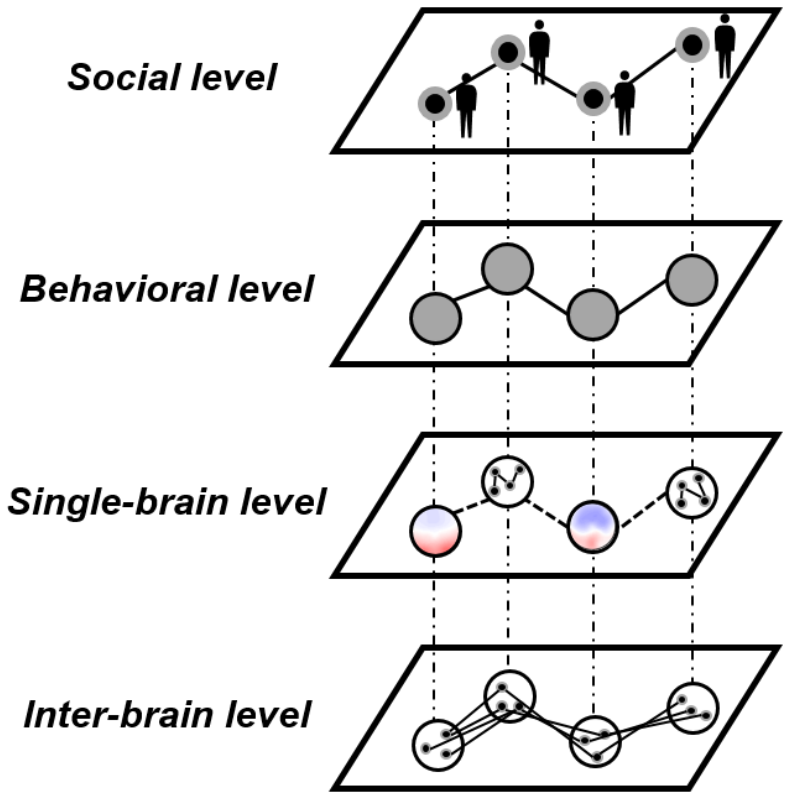
When I walked across the field, I picked this flower when I saw it. I told myself that this is the most beautiful one. Of course, I saw many beautiful flowers afterwards. But I still believe that the flower in my hands is the most beautiful one. So I bring it to you now.

Interactive learning

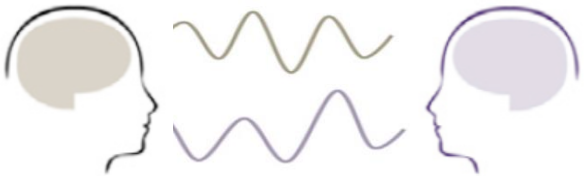
Much of human learning emerges as a result of interaction with others

(Marchiori and Warglien, *Science*, 2008; Verga and Kotz, 2019; Pan et al., 2018).

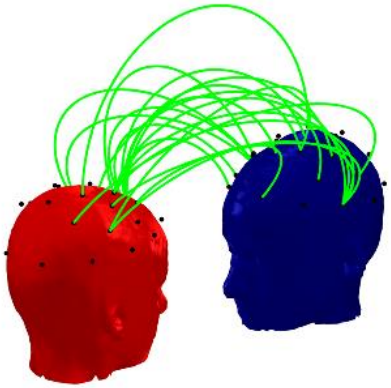
How the human brain supports interactive learning?



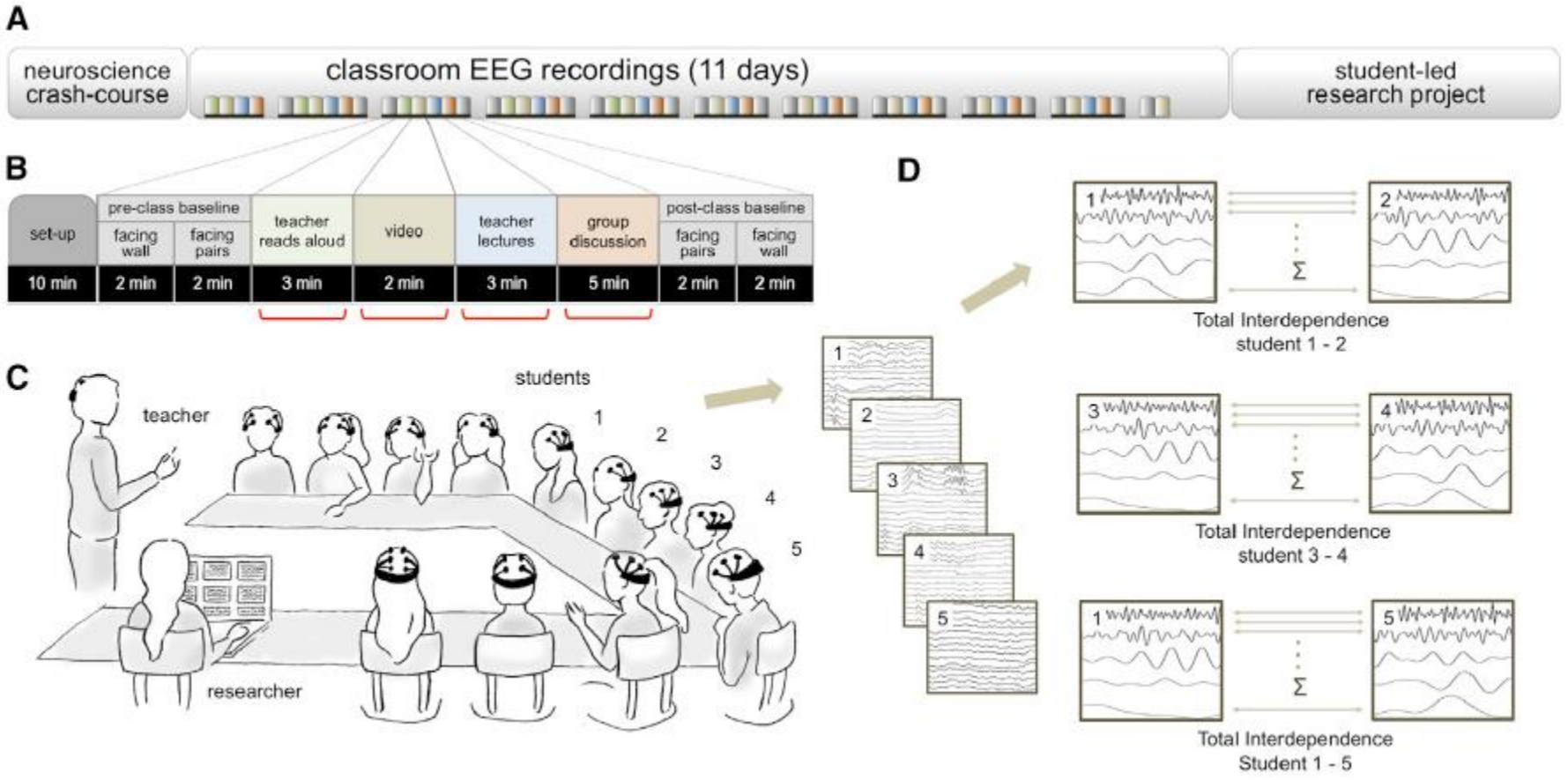
Two-person neuroscience
'Hyperscanning'



Interpersonal brain synchronization (IBS)

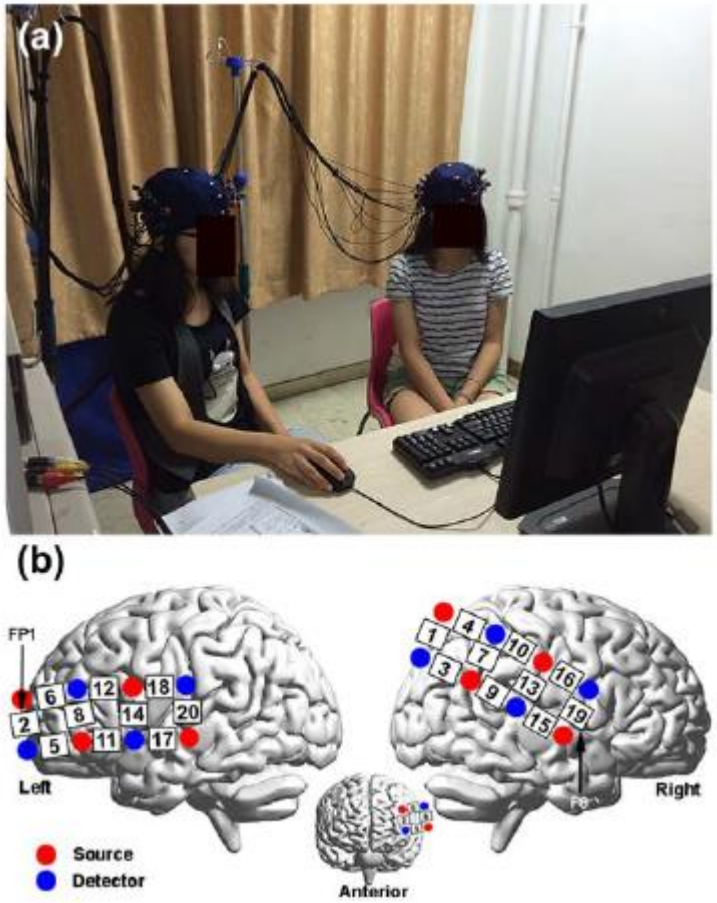


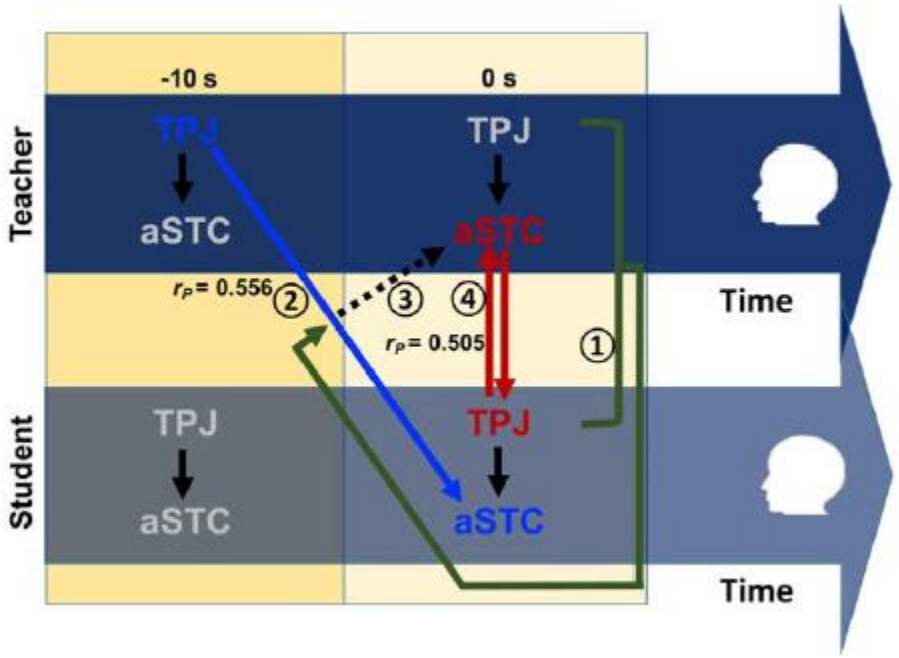
Brain-to-brain coupling tracks interactive learning



Bevilacqua et al., *JoCN*, 2019; Dikker et al., *Curr Biol*, 2017

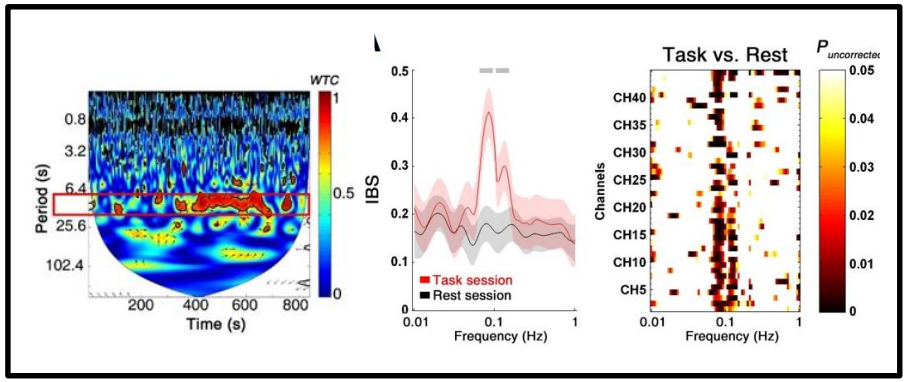
Brain-to-brain coupling tracks interactive learning

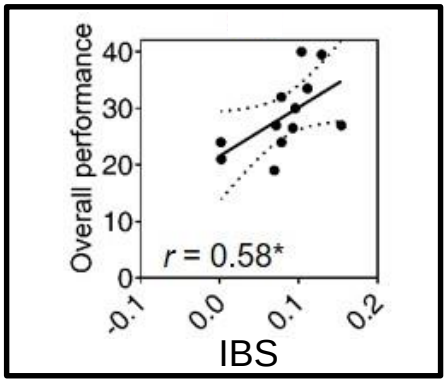


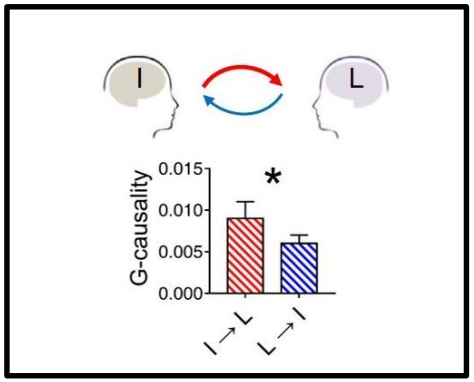


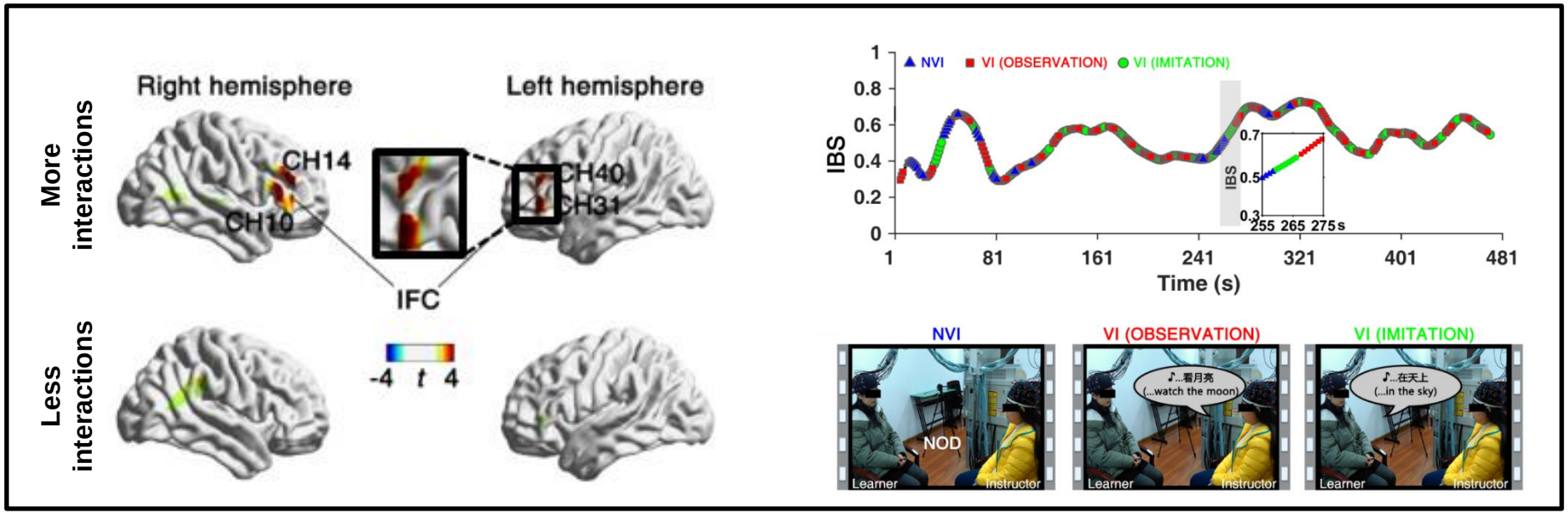
Zheng et al., *HBM*, 2018

Brain-to-brain coupling tracks interactive learning



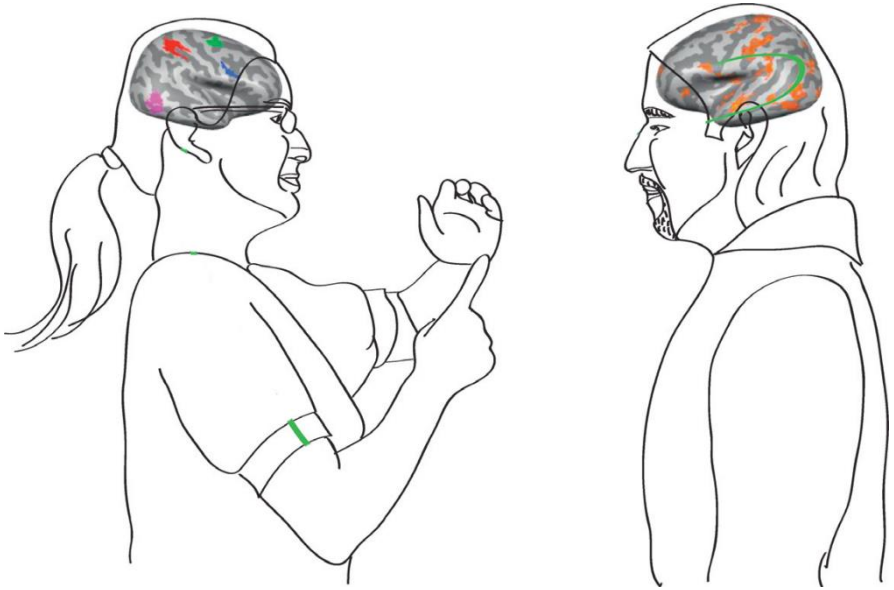






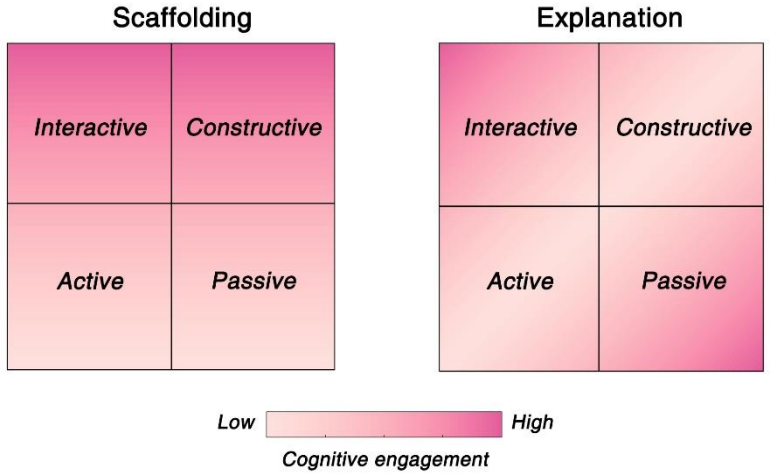
Pan et al., *NeuroImage*, 2018

Verbal instruction
(e.g., instructional approaches)



Instructor ***Learner***

ICAP framework for the scaffolding and explanation instructions



Chi and Wylie, 2014

Research questions

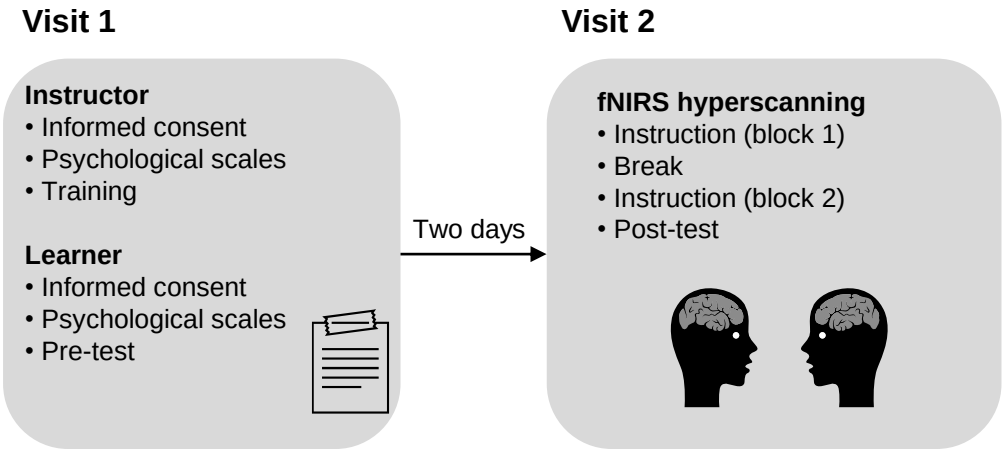
- Whether instructional approaches modulate brain-to-brain coupling during interactive learning? (Wavelet Transform Coherence analysis)

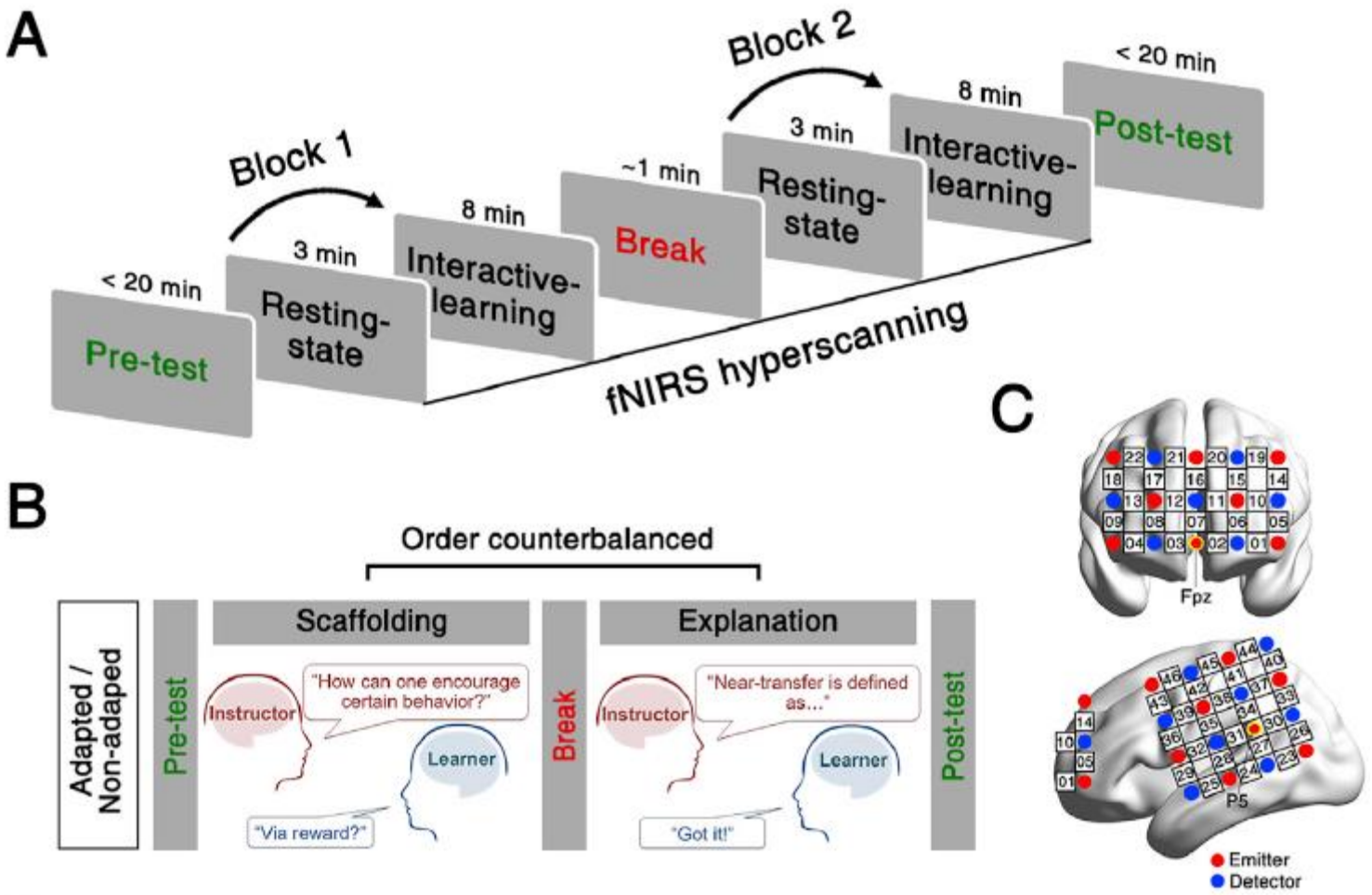
- Whether brain-to-brain coupling is specifically driven by certain instructional behavior? (Video coding analysis)

- To what extent scaffolding strategies can be distinguished from explanation strategies in the neural data? (Decoding analysis)

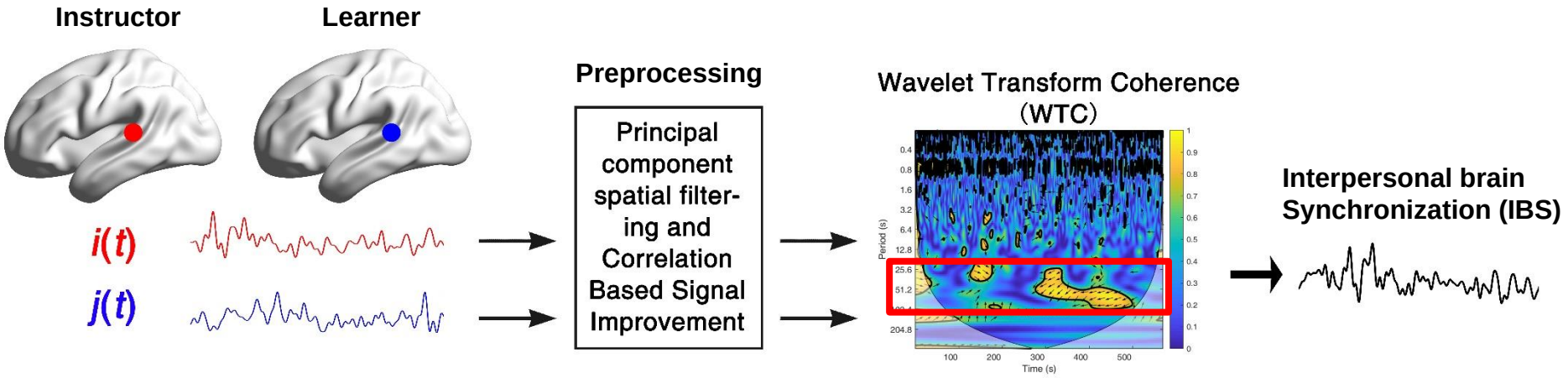
Methods

- *Participants*. 48 females, 24 dyads
- *Materials*. Two sets of psychological concepts (*reinforcement* and *transfer*)
- *Experimental factors*:
  - Instructional Strategy (Scaffolding vs. Explanation)
  - Instructional Personalization/Adaptation (Personalized vs/ Non-personalized)




A
< 20 min
Pre-test
Block 1
3 min
Resting-state
8 min
Interactive-learning
~1 min
Break
Block 2
3 min
Resting-state
8 min
Interactive-learning
< 20 min
Post-test
fNIRS hyperscanning
B
Order counterbalanced
Adapted / Non-adaped
Pre-test
Scaffolding
Instructor
"How can one encourage certain behavior?"
Learner
"Via reward?"
Break
Explanation
Instructor
"Near-transfer is defined as..."
Learner
"Got it!"
Post-test
C
Fpz
P5
Emitter
Detector

1. Global effect (heart-beat, respiration, blood pressure, etc)
2. Motion artefacts

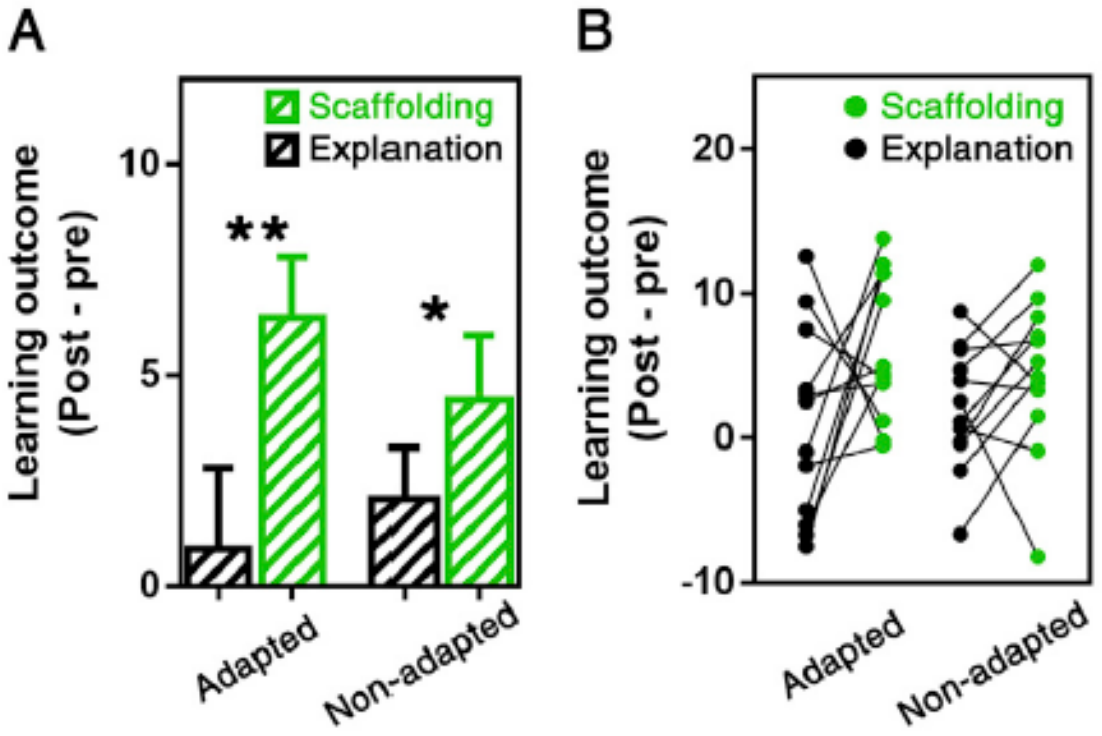


$$\mathrm{WTC}(t,s) = \frac{|\langle s^{-1}W^{ij}(t,s)\rangle|^2}{|\langle s^{-1}W^{i}(t,s)\rangle|^2 |\langle s^{-1}W^{j}(t,s)\rangle|^2}$$

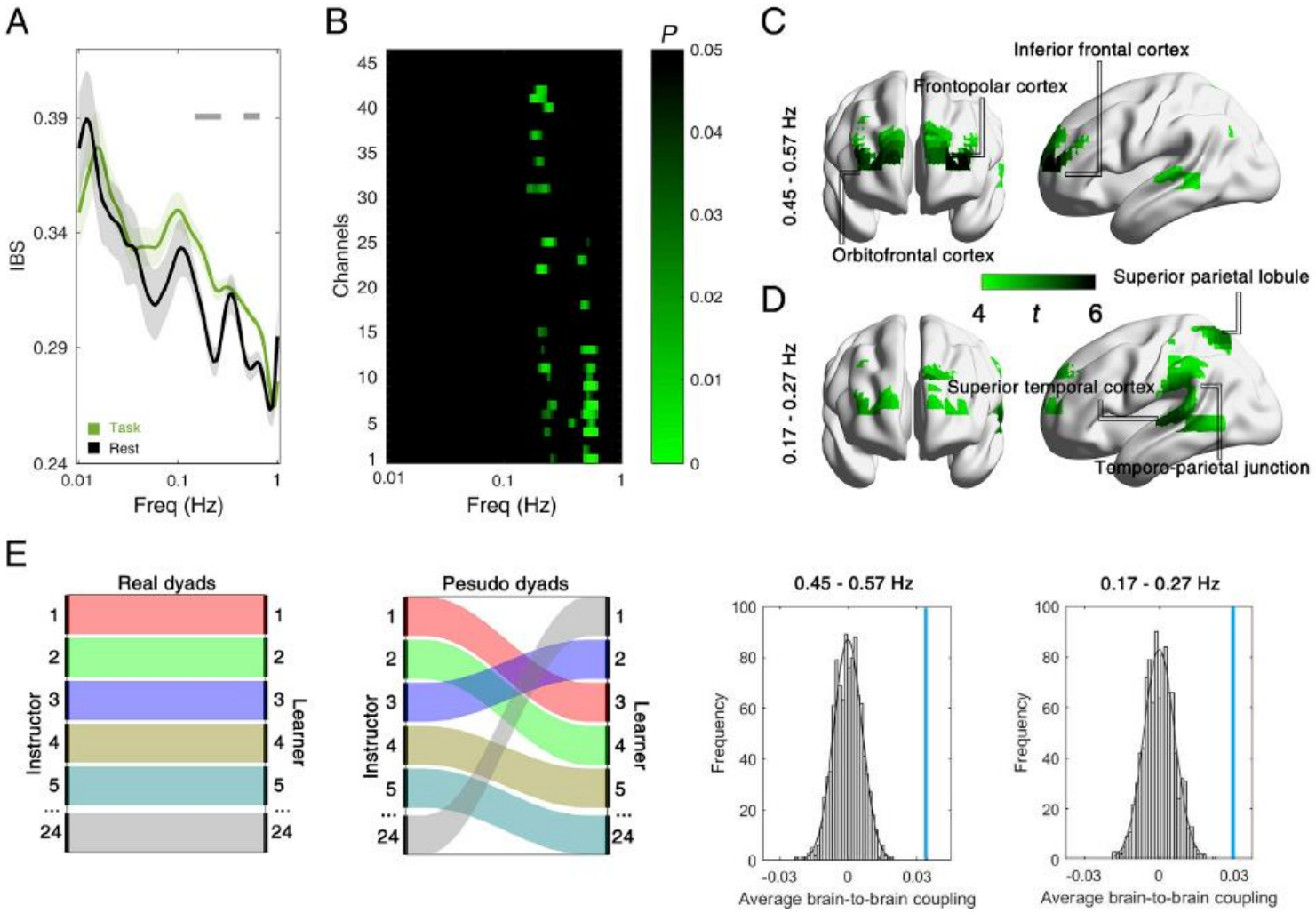
Wavelet function: *Morlet* wavelet

Also refer to: Zhang, X., Noah, J. A., Dravida, S., & Hirsch, J. (2020). **Optimization of wavelet coherence analysis as a measure of neural synchrony during hyperscanning using functional near-infrared spectroscopy**. *Neurophotonics*, *7*(1), 015010.

Behavioral performance



Interactive learning induces frequency-specific widespread brain-to-brain coupling



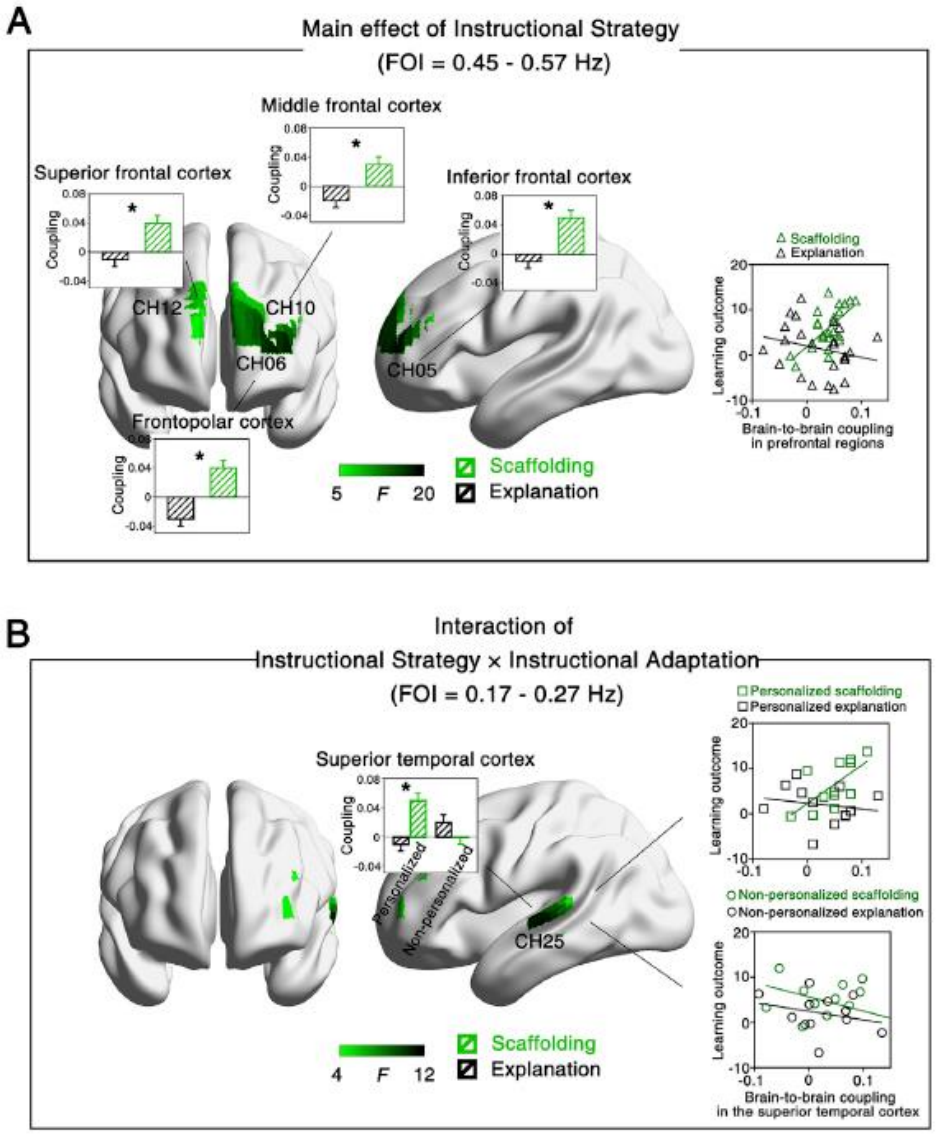
Interactive learning induces frequency-specific widespread brain-to-brain coupling

Determination of frequency of interest (FOI):

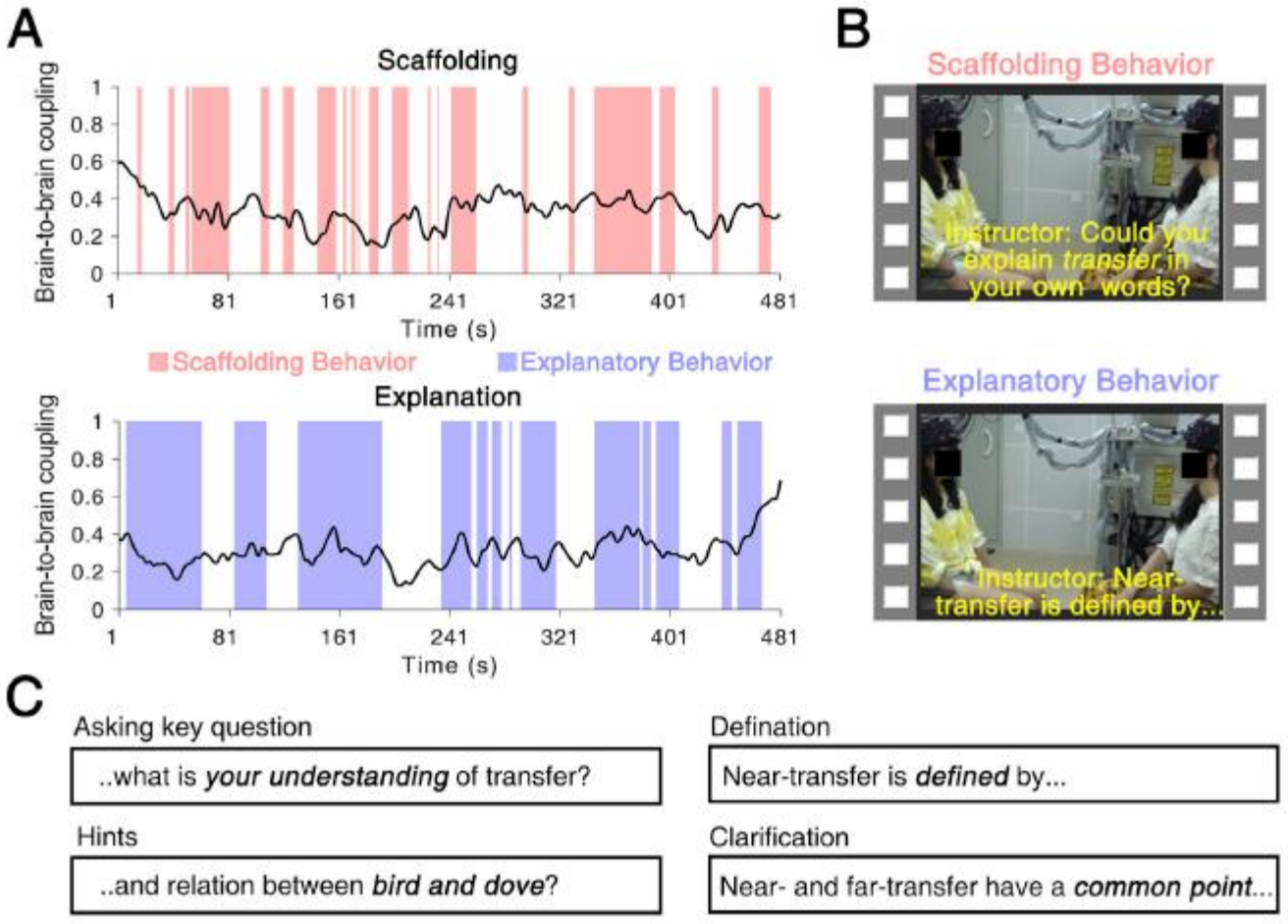
1. Temporal structure of a trial
2. Previous studies using the same paradigm
3. Task vs. rest across frequencies
4. Real pairs vs. null distribution of random pairs, permutation
5. Direct conditional comparisons across frequencies

Pitfall:
Double dipping:
Step 1. Conditional comparison (to determine FOI)
Step 2. Using this FOI for conditional comparison

Instruction modulates brain-to-brain coupling within instructor-learner dyads



Linking instructional behaviors with brain-to-brain coupling



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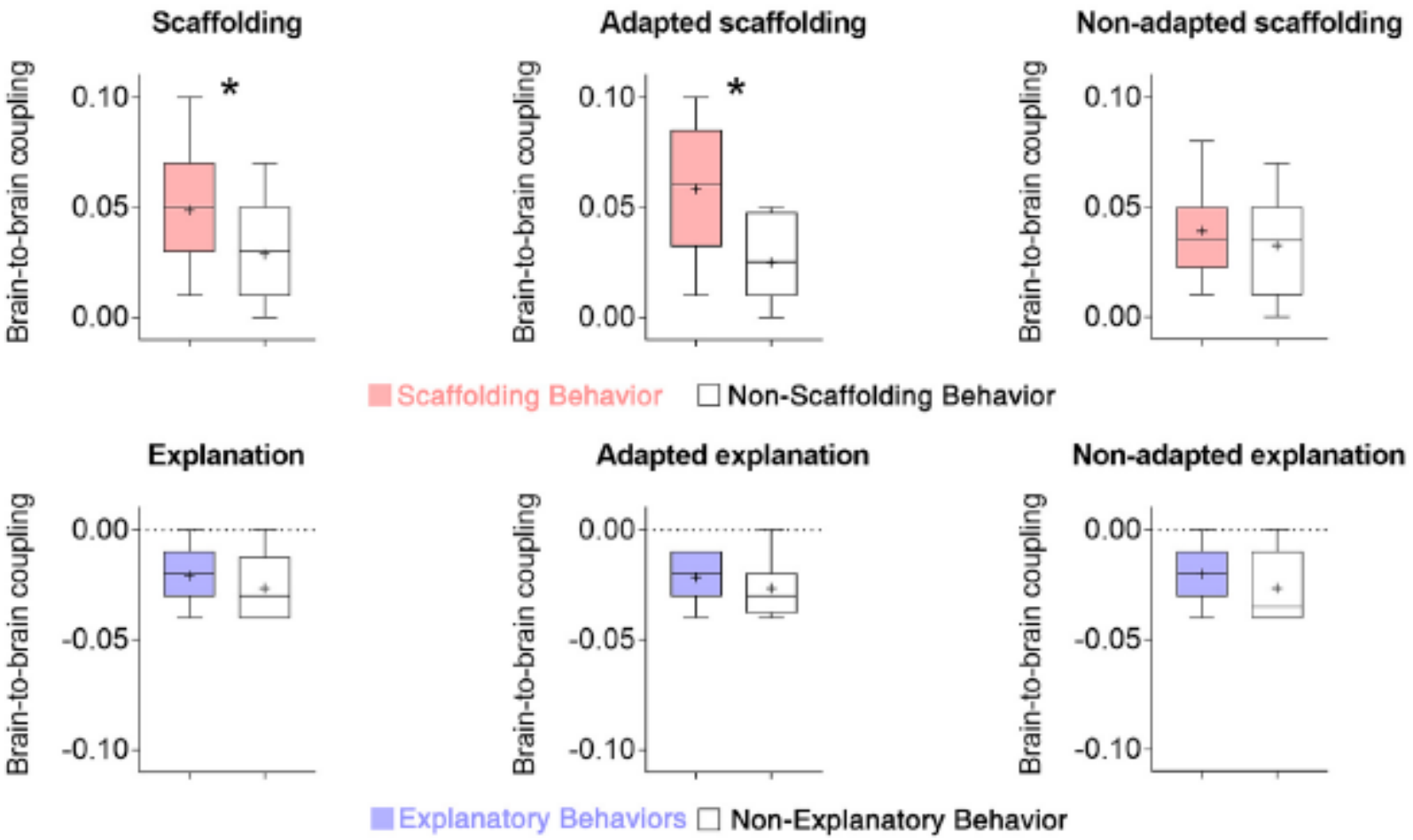
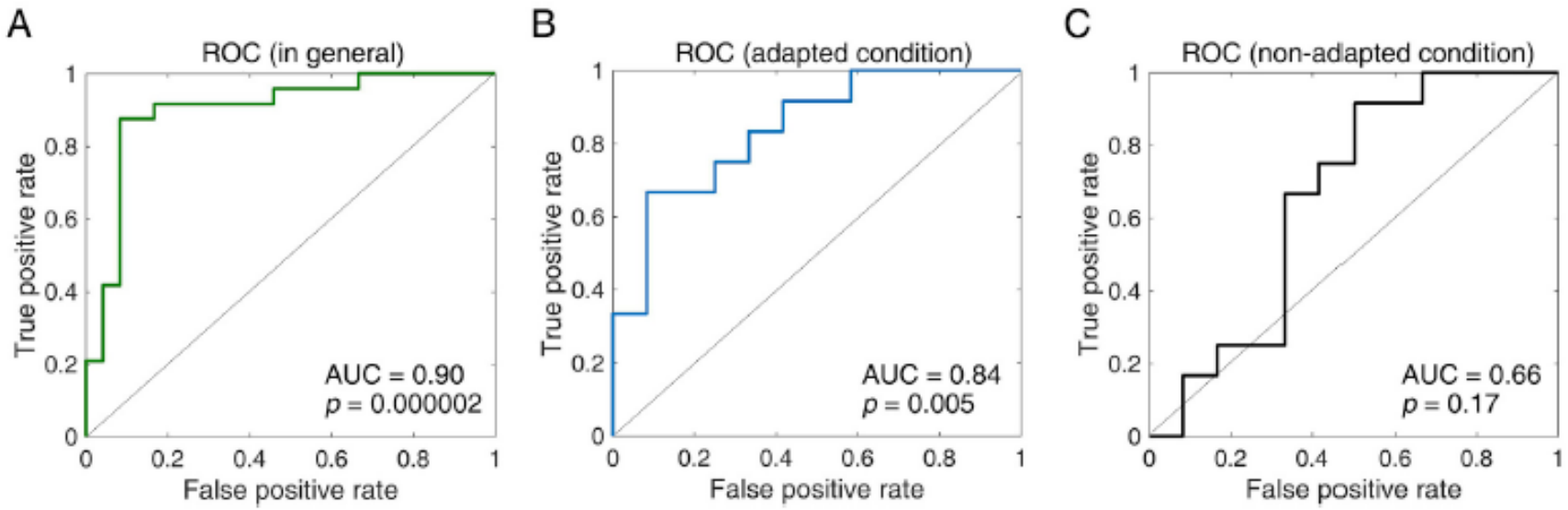


Decoding instructional strategy from brain-to-brain coupling



Discussion

- *Using two brains to study learning and instruction (two-person educational neuroscience)*

- *The role of prefrontal and temporal cortices in brain-to-brain coupling (shared intentionality, predictive coding)*

- *Linking brain imaging findings to pedagogical practice (favoring a constructivist approach)*

Limitations

- *Spatial resolution*
- *Regions of interest*
- *Statistical power*

Take home messages

- *Verbal instruction modulates instructor-learner brain coupling: Scaffolding vs. Explanation elicited larger brain coupling;*

- *Such brain coupling enhancement was driven by dynamic scaffolding representations;*

- *Instructor-learner brain coupling (compared to individual brain activation) was successfully used to classify instructional approaches*