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Introduction

- Despite the fundamental role of speech perception in first language acquisition, the role of speech perception in foreign language learning outcomes remains unknown.
- Nonnative in adults varies substantially across individuals [1].
- Better behavioral performance and stronger neural responses discriminating non-native speech sounds are related to greater success learning foreign language vocabulary and phonology [2-5].

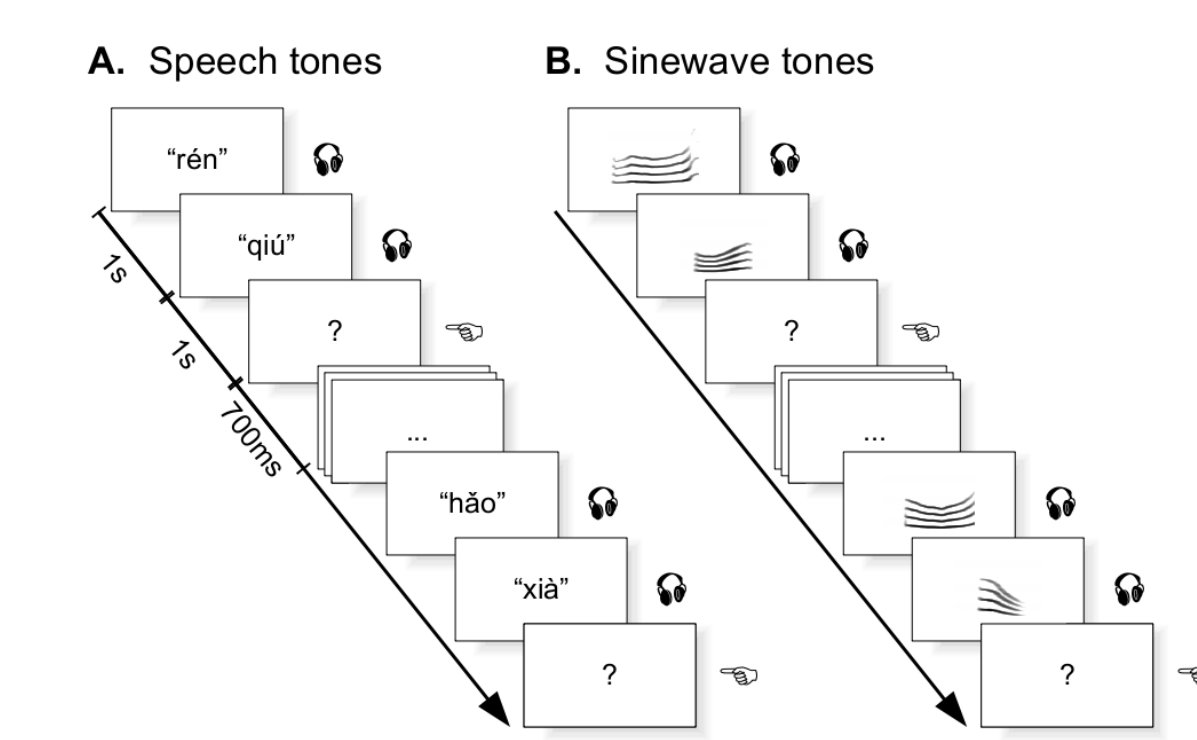
Research Questions

How does the interplay between speech perception and language learning – and particularly the neural mechanisms underlying these processes – determines the long-term retention of holistic, real-world foreign language skills?

Neuroimaging Methods

Tone discrimination fMRI task

- 96 pairs of Mandarin single words
 - ✧ Different syllables; Different speakers
- 96 pairs of corresponding sinewave tones
- TR = 2.7 s, TA = 0.5 s, design



Task fMRI analysis

- FSL v5.0.9, Nipype v0.8
- Speech vs. Sinewave
- Randomise function, 5000 permutations

Resting fMRI

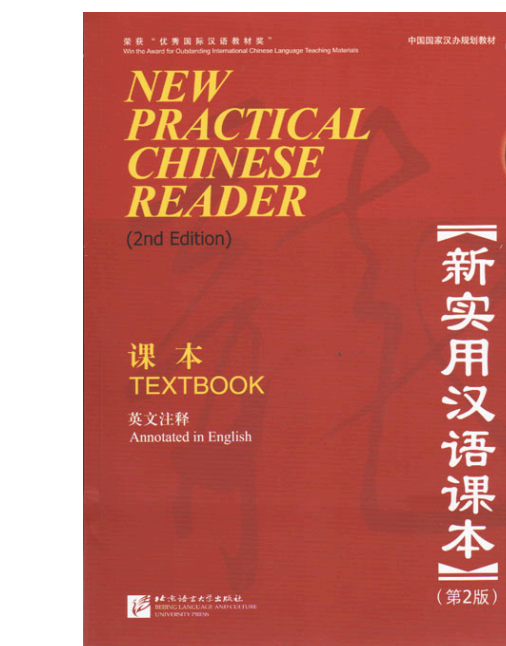
- Scan time: 6 min 15 sec
- TR = 2.5 s, 37 slices (3.5 mm thick)

Resting functional connectivity analysis

- SPM v8, ART, CONN v13.p
- aCompCor for non-neuronal noise sources
- Anatomically defined seed in left and right IFG

Participants

- 24 native English speakers (8 females and 16 males)
- Age: 18 - 33, Mean: 23.1



- 3.5 hours every day
- Highly-interactive classroom with 12-13 students
- 10 in-class quizzes, 11 assignments
- Mid-term and Final exams

Pre-training
DTI, task fMRI,
resting fMRI

4-week training

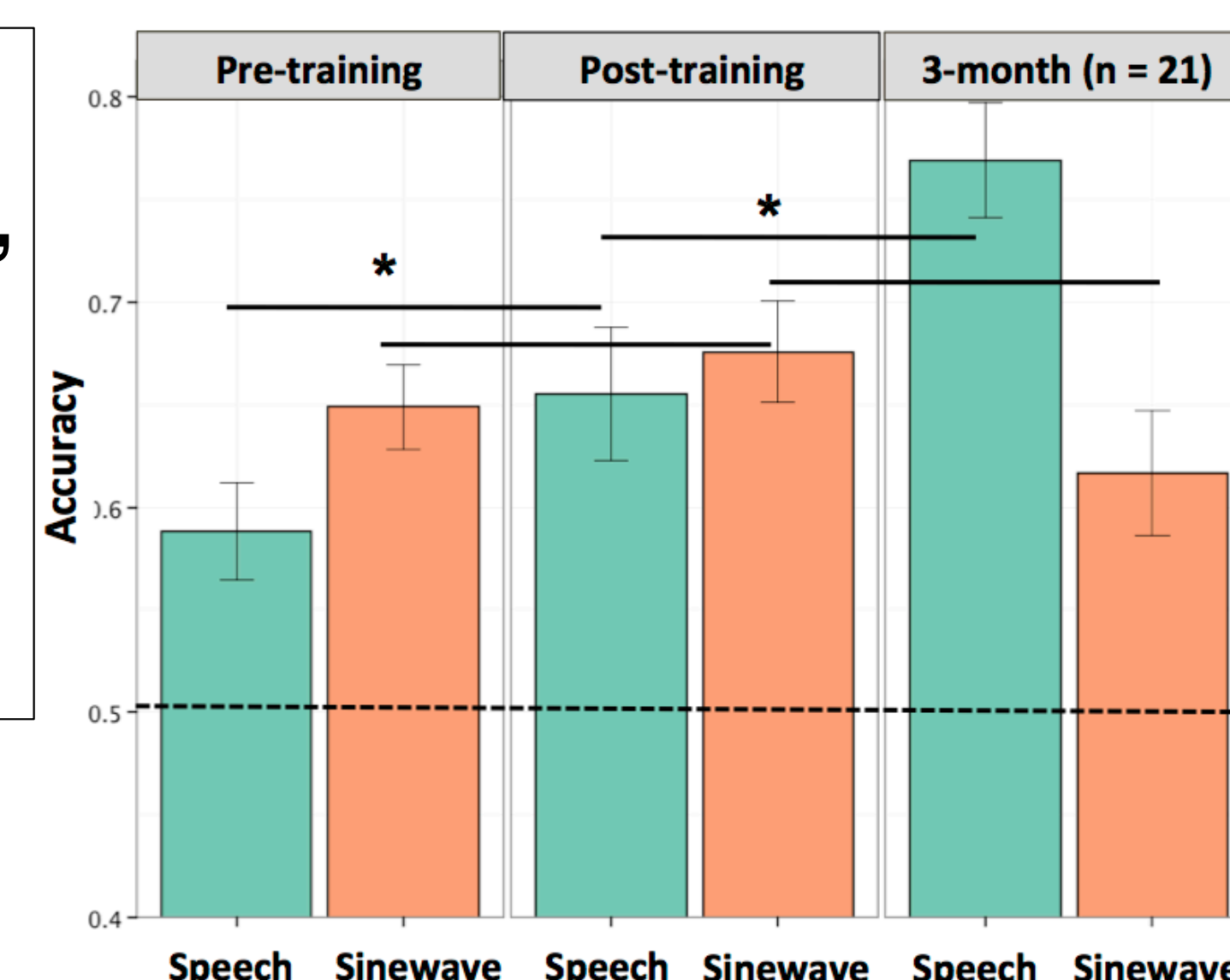
Post-training
DTI, task fMRI,
resting fMRI
Final Exams

12-week
no exposure

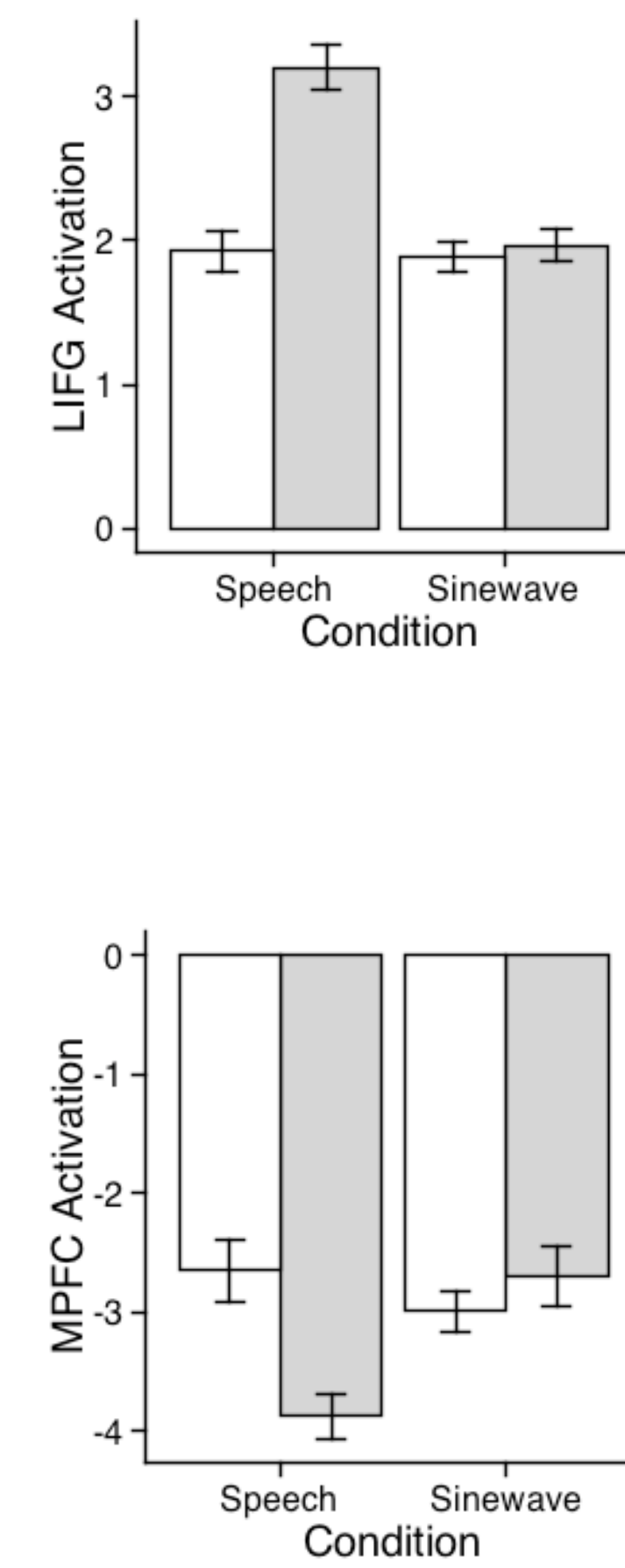
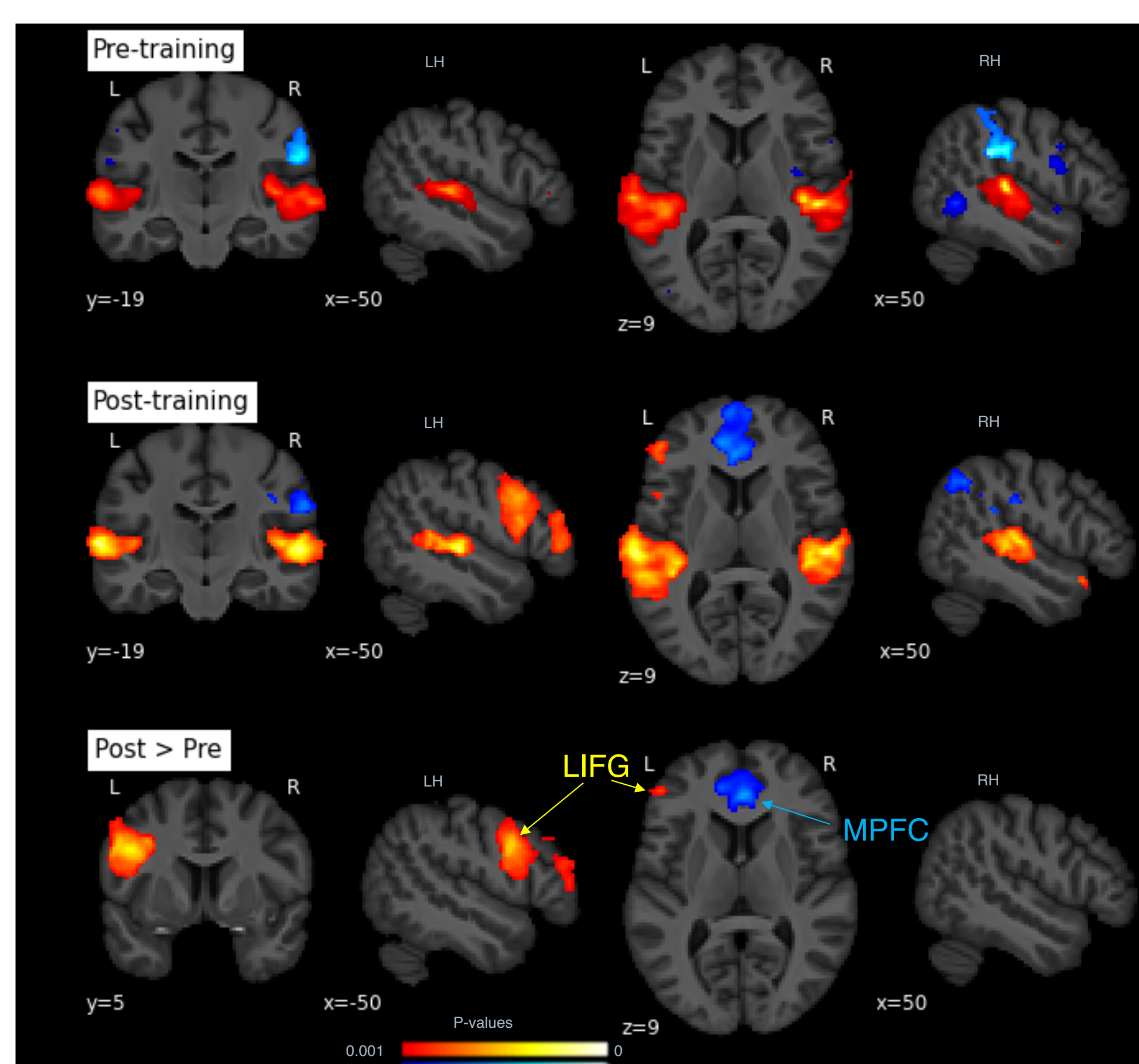
Day 90
Exams

Learning-induced Plasticity

- Enhanced ability in discriminating lexical tones, but not acoustic tones.
- Continuous consolidation even after the Mandarin training period.



- Greater sensitivity to lexical tones at LEFT IFG after training.
- Greater deactivation of MPFC (default mode network) after training.

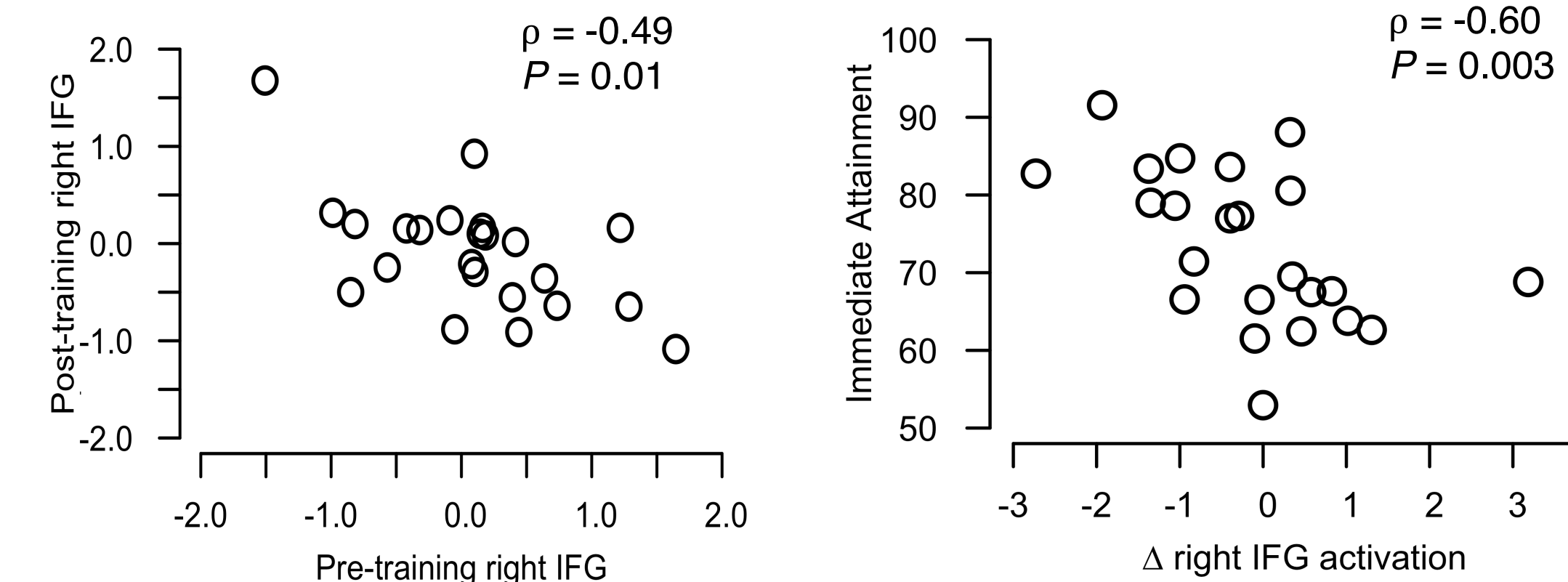
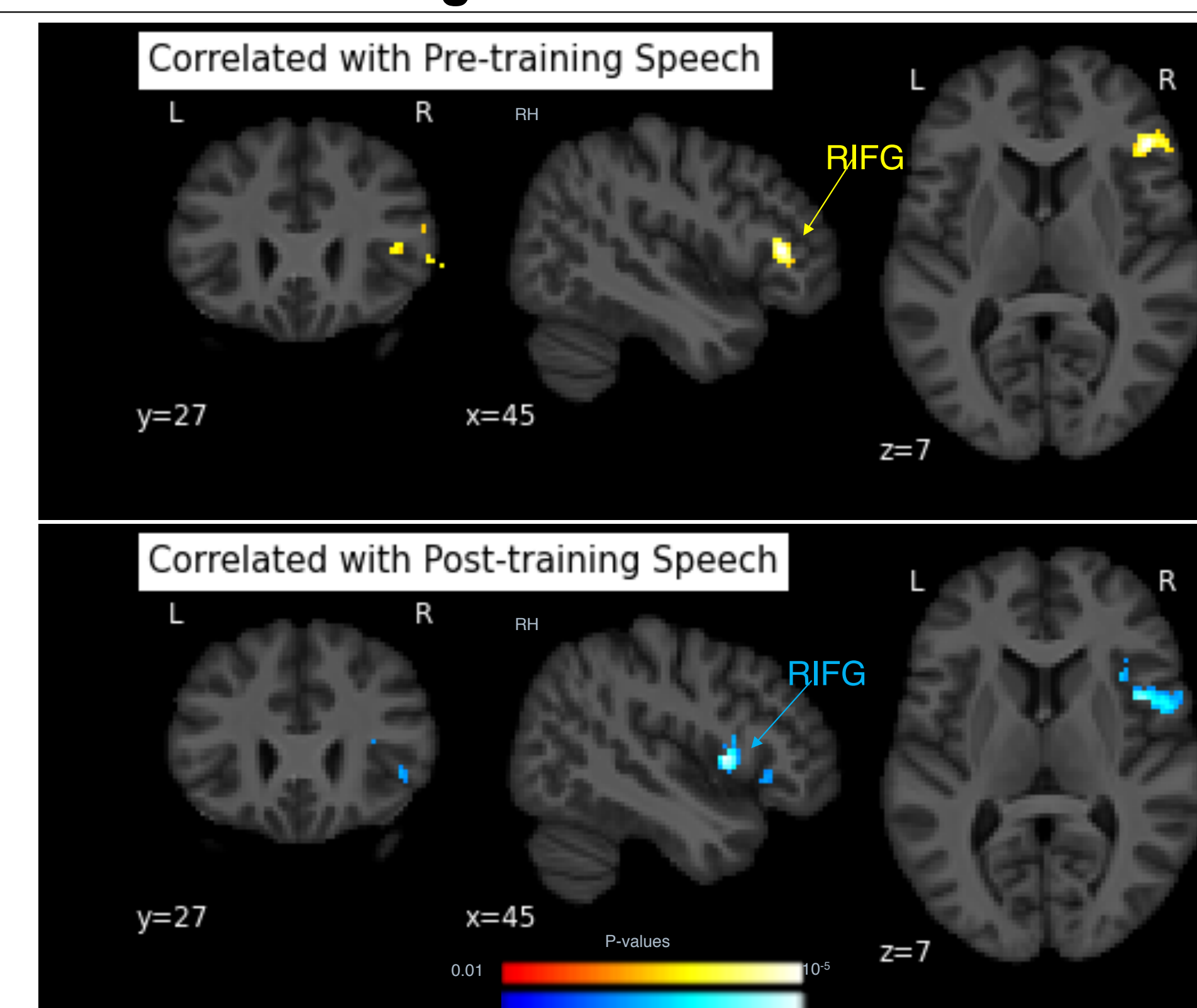


- Both inter-hemispheric connectivity and right IFG disengagement are associated with immediate attainment.

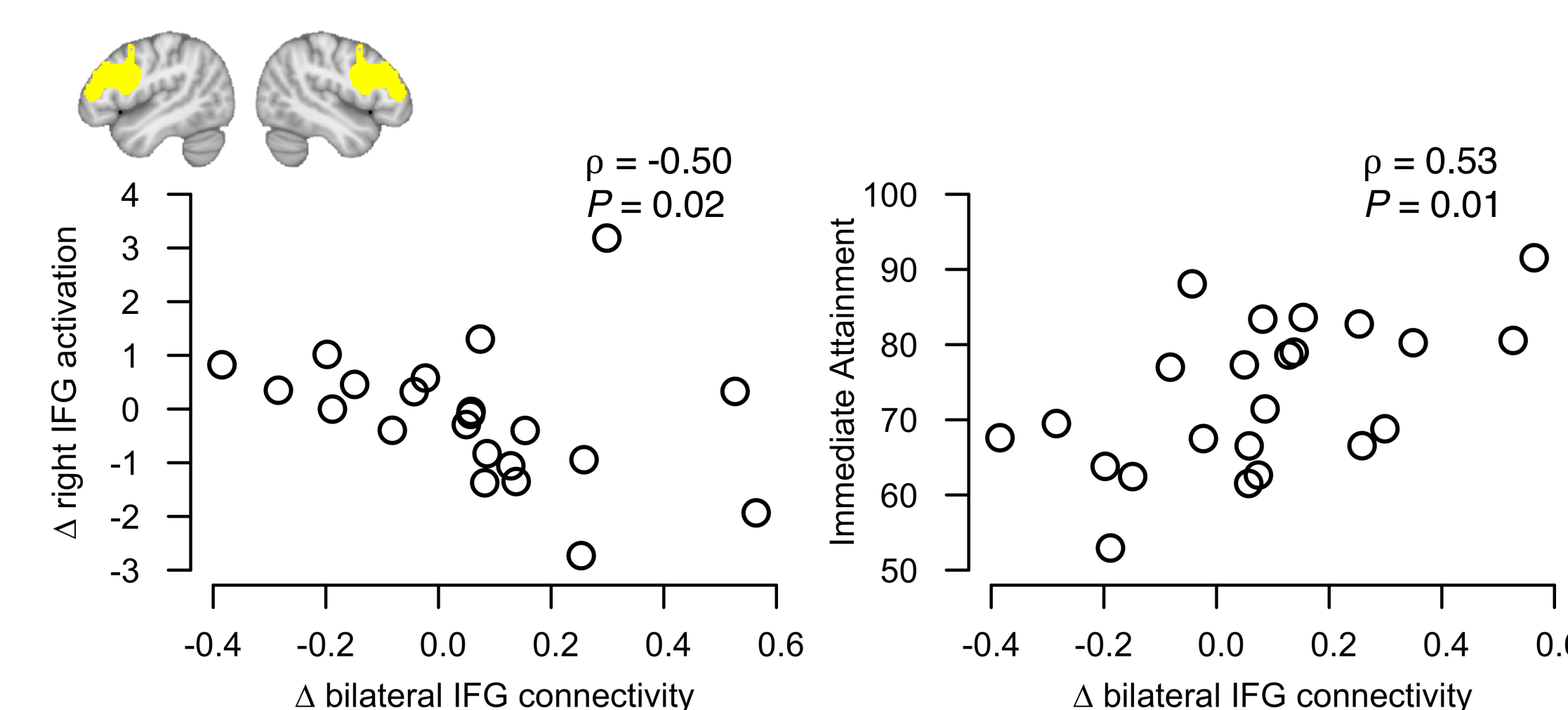
	Post – Pre LIFG	Post – Pre RIFG	Post – Pre rsfMRI
Post-training tone	-0.06 (0.78)	-0.78 (<0.0001)*	0.37 (0.08)
Immediate Attainment	0.16 (0.46)	-0.60 (0.003)*	0.53 (0.01)*

Post-training tone: Discrimination accuracy in the speech condition; * FDR-corrected $p < 0.05$

- Right IFG transitioned from positive engagement to disengagement in lexical tone processing after Mandarin training.



- Enhanced inter-hemispheric connectivity is associated with right IFG disengagement.

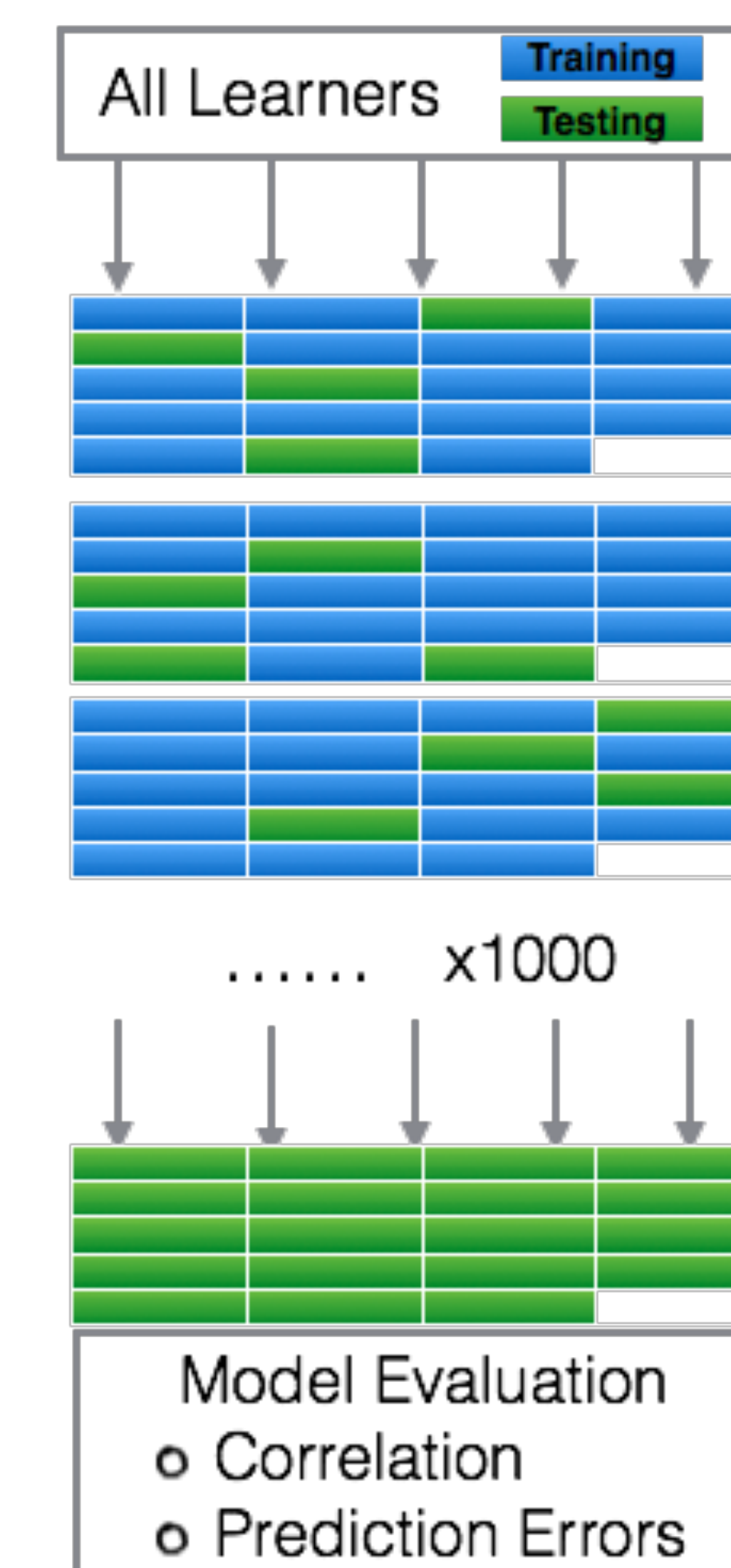


Behavioral and Neural Predictors

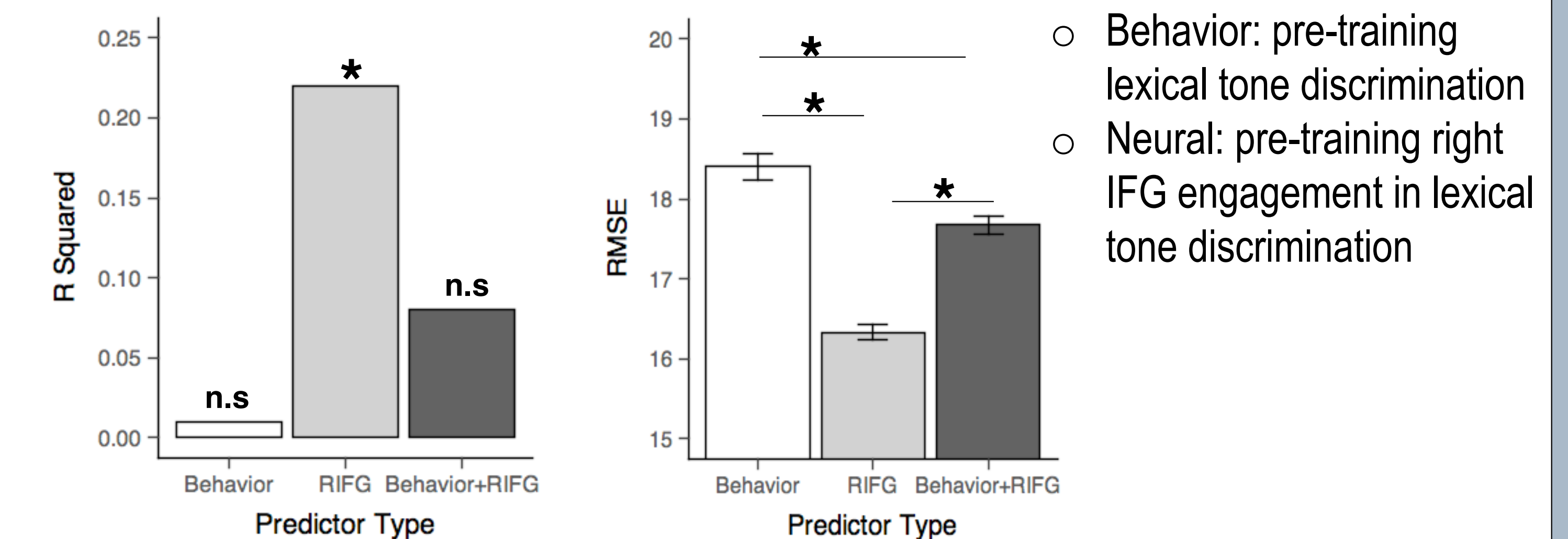
- Immediate attainment is best predicted by pre-training lexical tone discrimination accuracy.

	Pre-training		Post-training	
Proficiency	Speech	Sinewave	Speech	Sinewave
Post-training (N = 24)	$r = 0.63, p = 0.001^*$	$r = 0.39, p = 0.060$	$r = 0.53, p = 0.008^†$	$r = 0.47, p = 0.020^†$
Post + 90 days (N = 19)	$r = 0.34, p = 0.150$	$r = 0.39, p = 0.095$	$r = 0.21, p = 0.381$	$r = 0.11, p = 0.644$

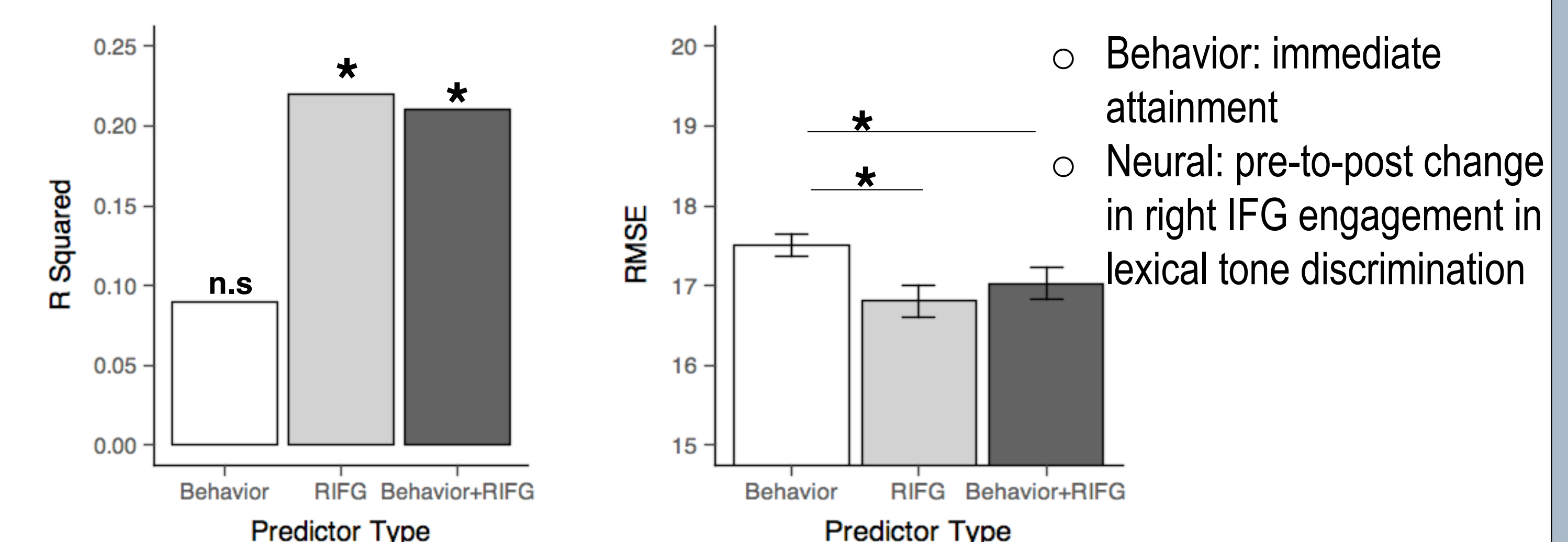
Cross-validation analysis of prediction models



- Long-term retention is best predicted by pre-training right IFG engagement in lexical tone discrimination.



- Long-term retention is best predicted by plasticity of right IFG (disengagement) in lexical tone discrimination.



Summary:

- The present study demonstrated how the brain organization of speech perception, a fundamental linguistic ability, has a long-lasting effect on adults' holistic acquisition of foreign language.
- Successful whole-language learning hinged on both initial engagement and subsequent disengagement of right IFG for foreign speech processing.
- Enhanced cross-hemispheric connectivity might support transition from initial right-to left-IFG engagement in speech perception.

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