Speech Processing and Plasticity in the Right Hemisphere Predict Real-world Foreign Language Learning In Adults

Zhenghan Qi[1, 2], Michelle Han[1], Yunxin Wang[1], Carlo de los Angeles[1], Qi Liu[1], Keri Garel[1], Ee San Chen[1], Susan Whitfield-Gabrieli[1], John Gabrieli[1], Tyler Perrachione[1, 3]

[1] Massachusetts Institute of Technology, [2] University of Delaware, [3] Boston University

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

A. Speech tones   B. Sinewave tones
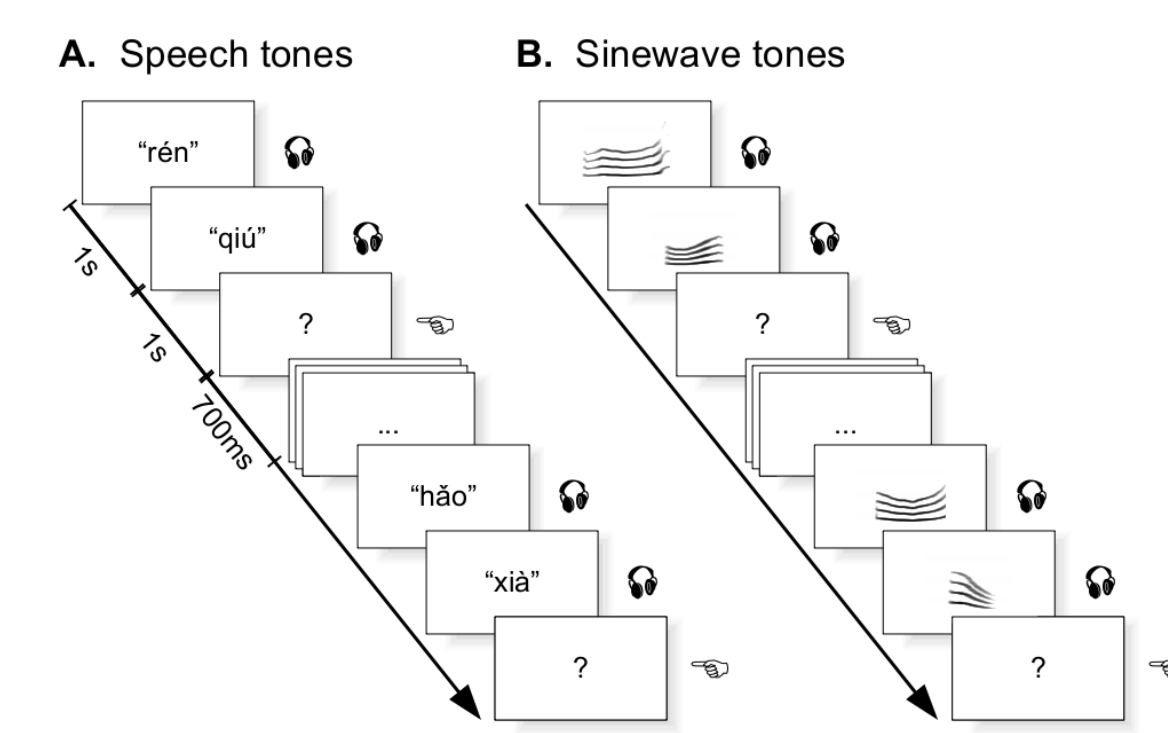
Task fMRI analysis
- FSL v5.0.9, Nipype v0.8
- Speech vs. Sinewave
- *Randomise* function, 5000 permutations
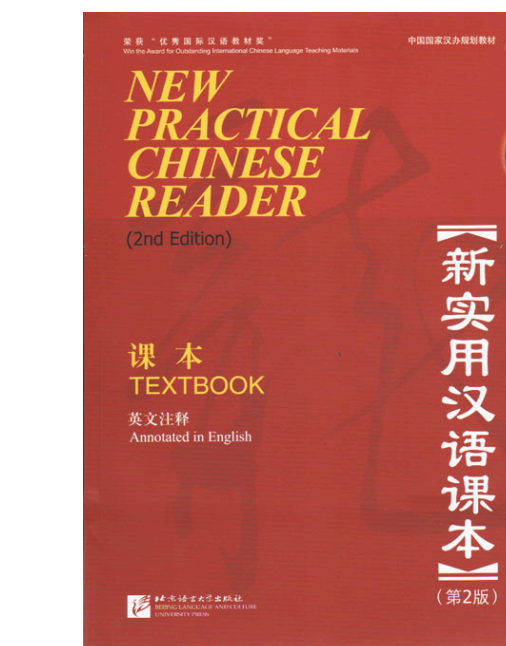
Resting fMRI
- Scan time: 6 min 15 sec
- TR = 2.5 s, 37 slices (3.5 mm thick)

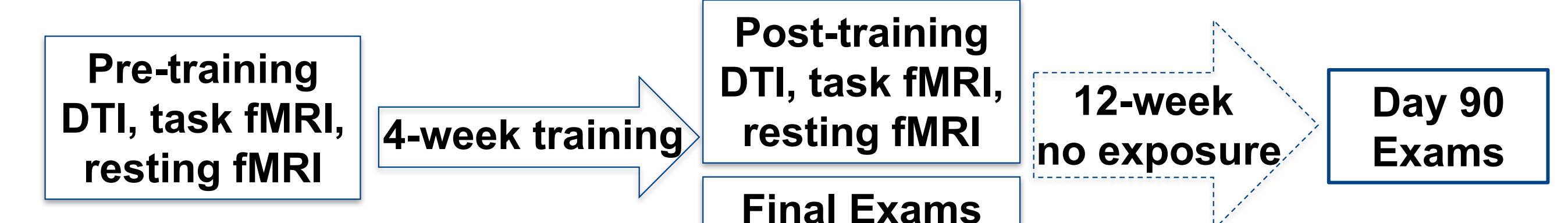### Resting functional connectivity analysis
- SPM v8, ART, CONN v13.p
- aCompCor for non-neuronal noise sources
- Anatomically defined seed in left and right IFG

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
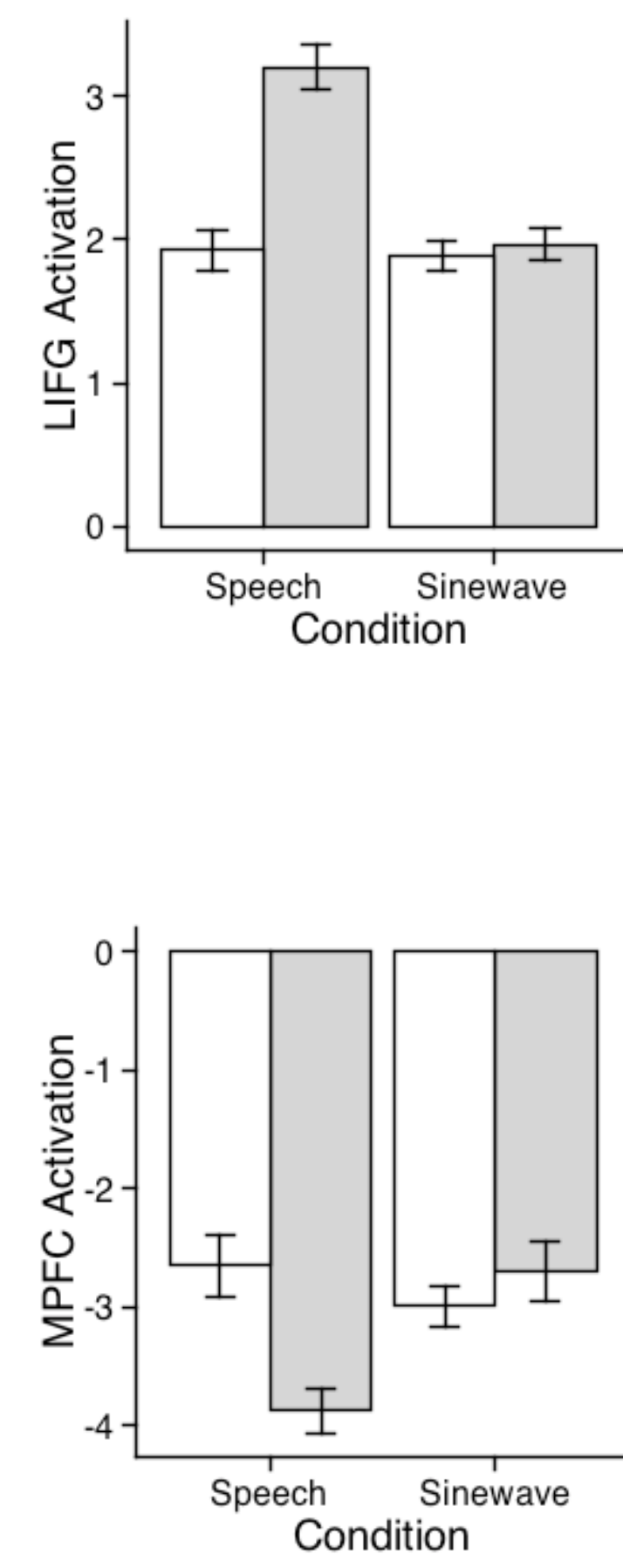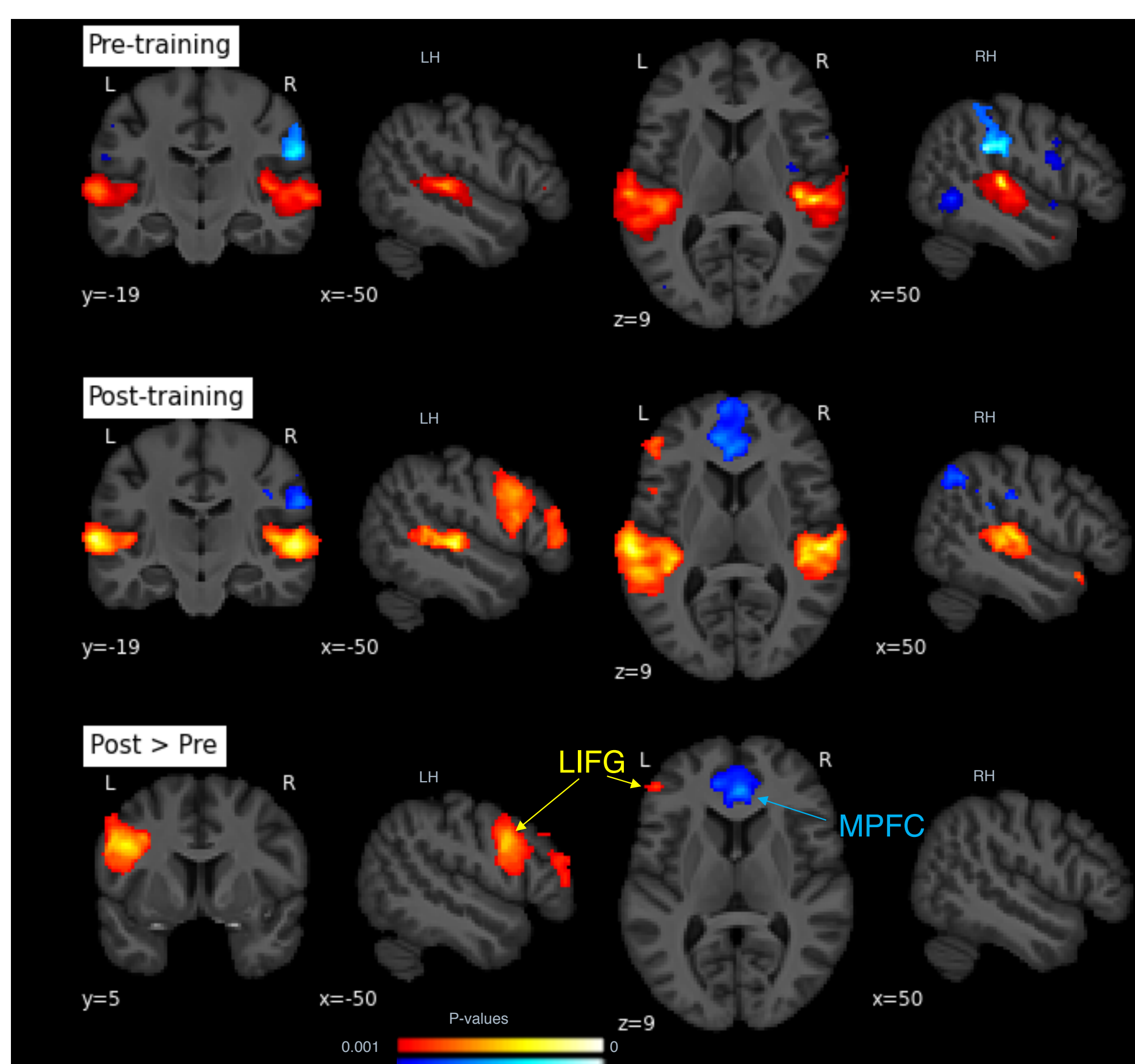- 10 in-class quizzes, 11 assignments
- Mid-term and Final exams

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
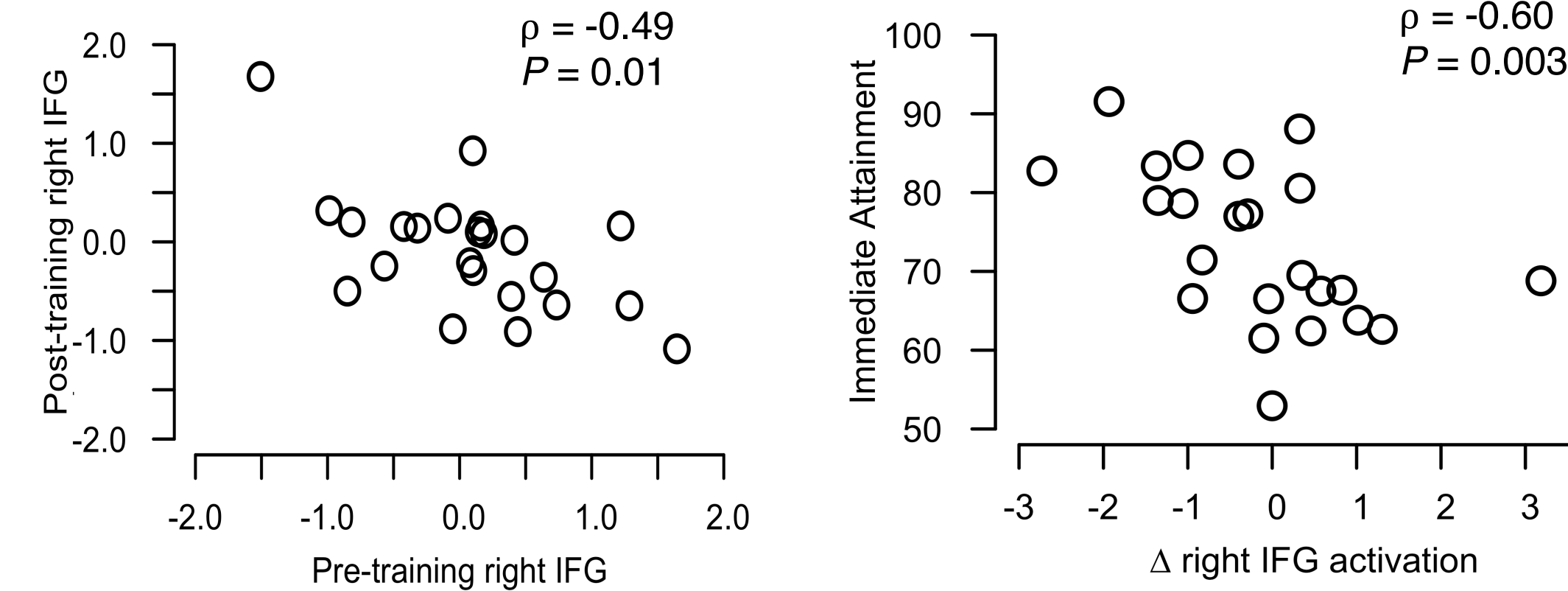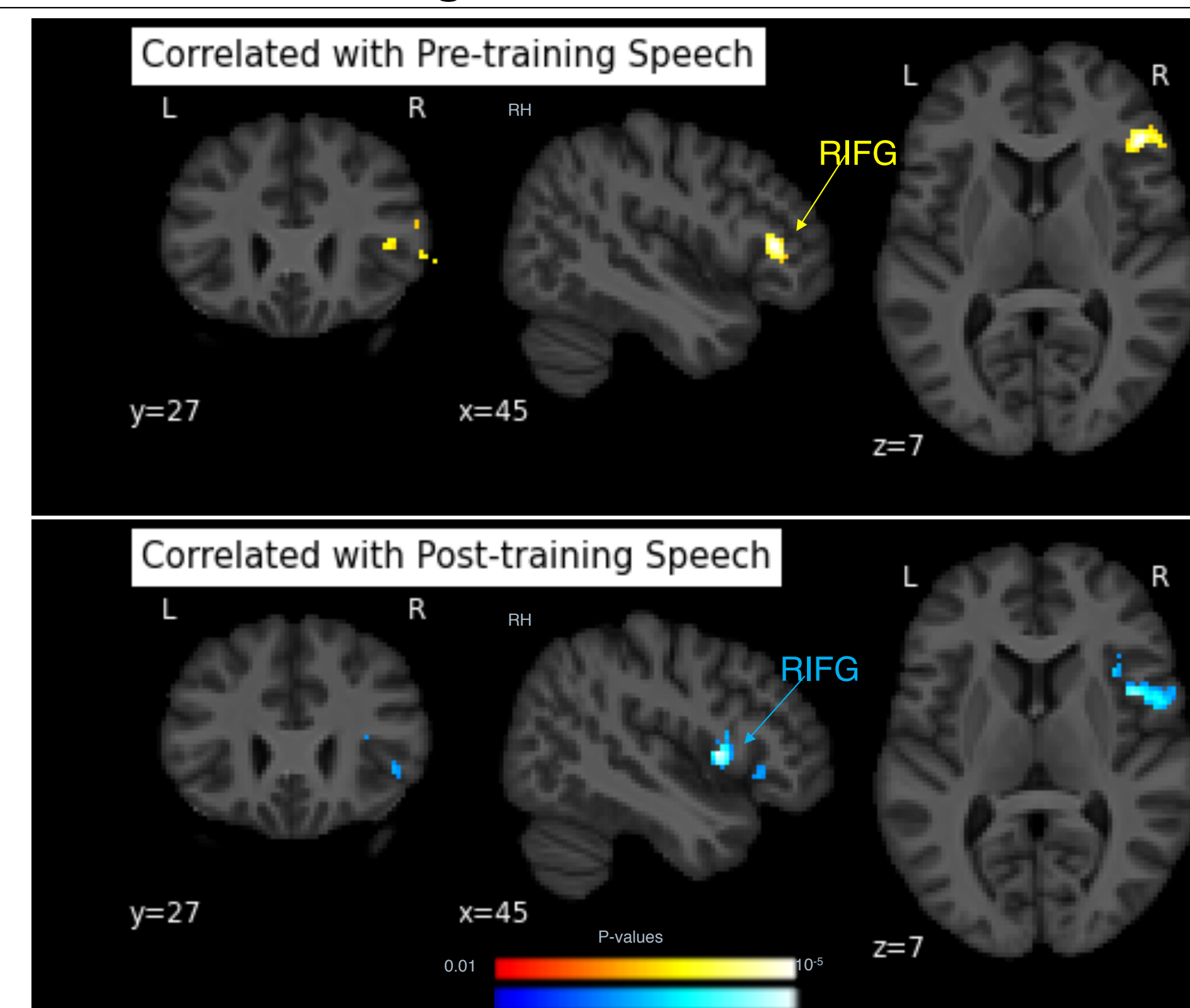
Learning-induced Plasticity

a) Enhanced ability in discriminating lexical tones, but not acoustic tones.
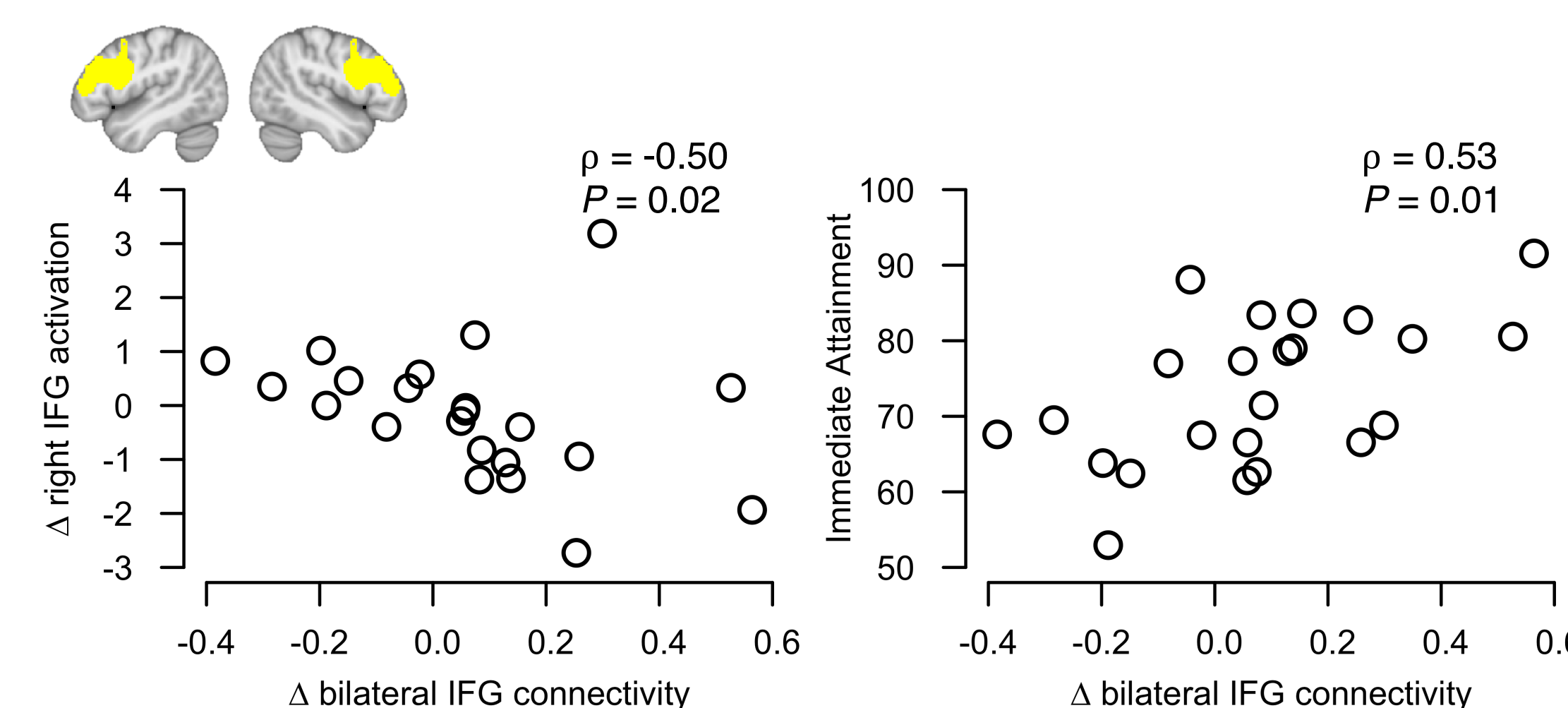b) Continuous consolidation even after the Mandarin training period.
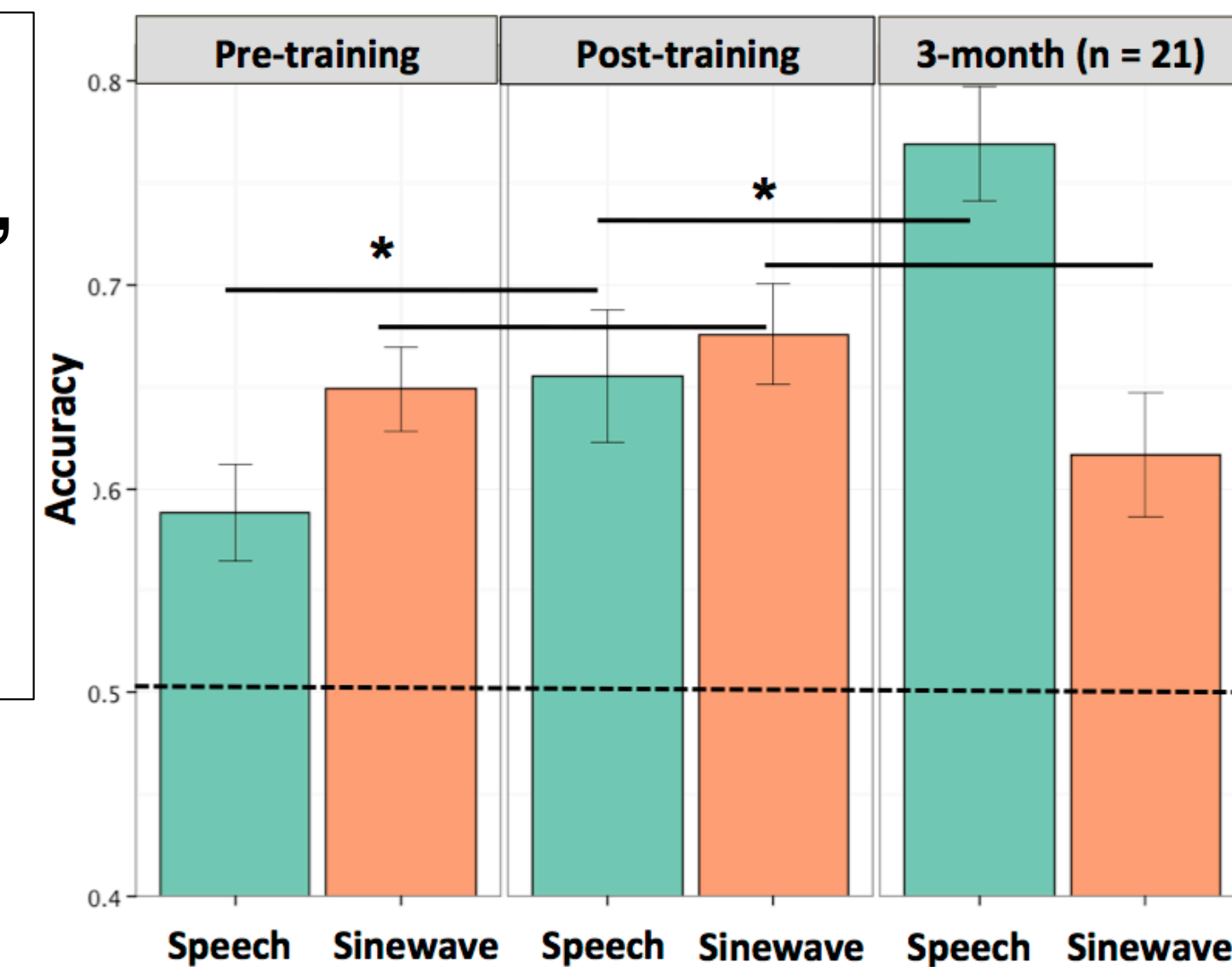
c) Greater sensitivity to lexical tones at LEFT IFG after training.
d) Greater deactivation of MPFC (default mode network) after training.

g) 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

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

Correlated with Pre-training Speech

Correlated with Post-training Speech

ρ = -0.49, P = 0.01
ρ = -0.60, P = 0.003

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

ρ = -0.50, P = 0.02
ρ = 0.53, P = 0.01

Behavioral and Neural Predictors

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

| Proficiency | Pre-training | | Post-training | |
	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
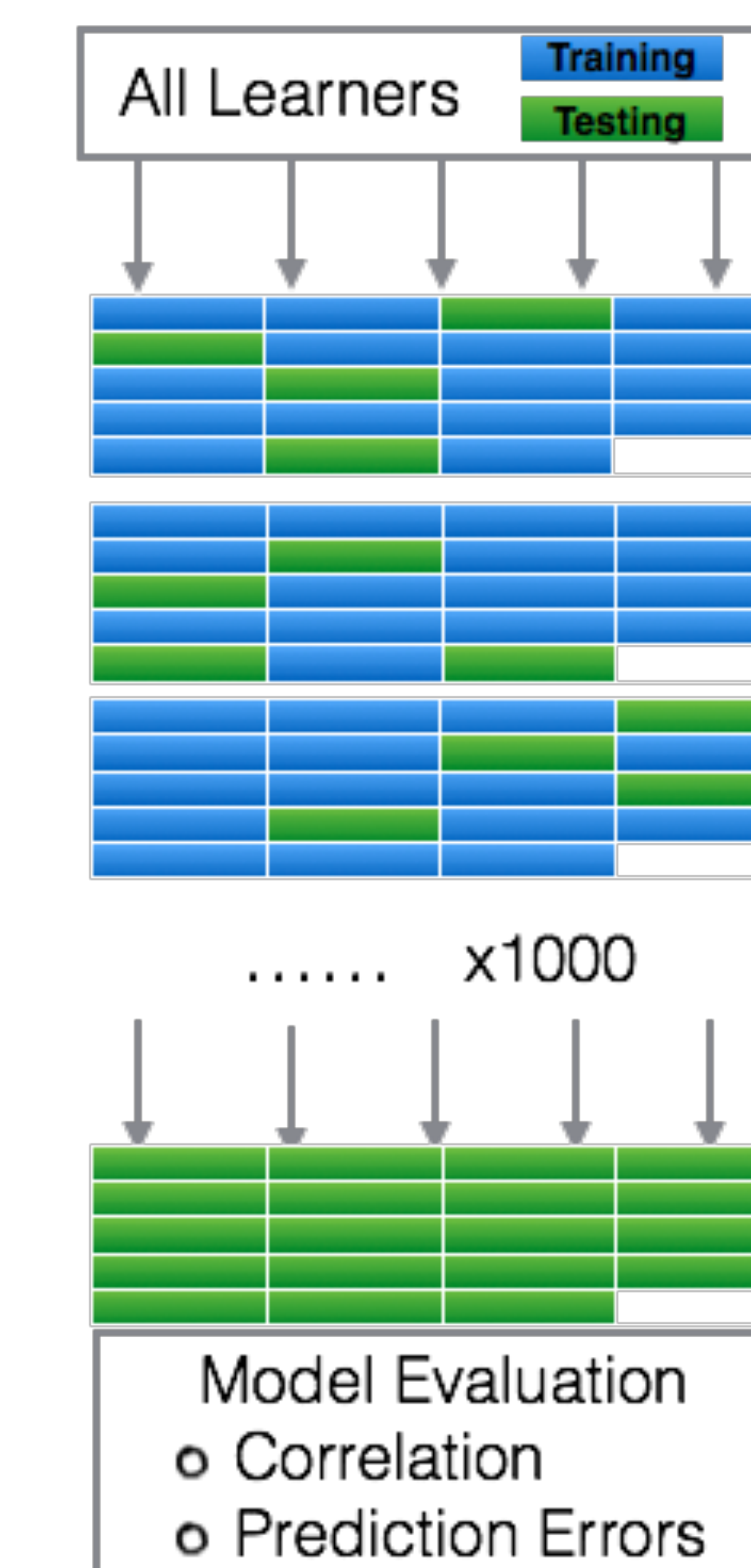
All Learners — Training / Testing

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Model Evaluation
- Correlation
- Prediction Errors

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

- Behavior: pre-training lexical tone discrimination
- Neural: pre-training right IFG engagement in lexical tone discrimination
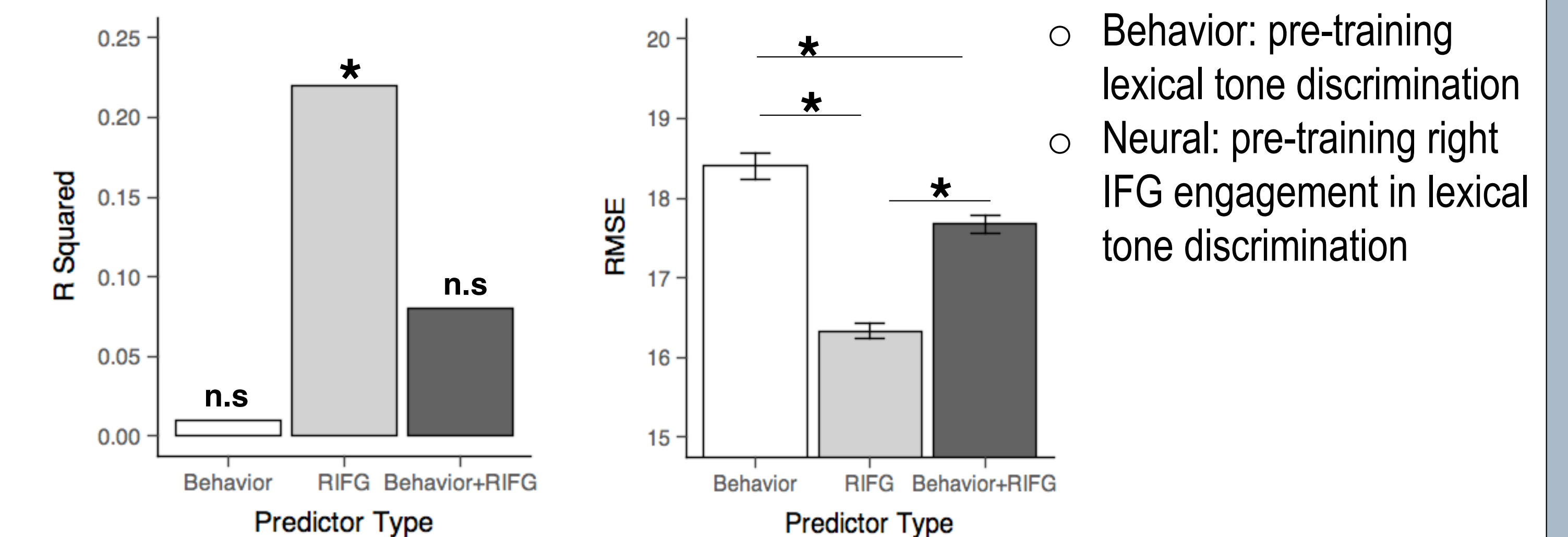
c) Long-term retention is best predicted by plasticity of right IFG (disengagement) in lexical tone discrimination.

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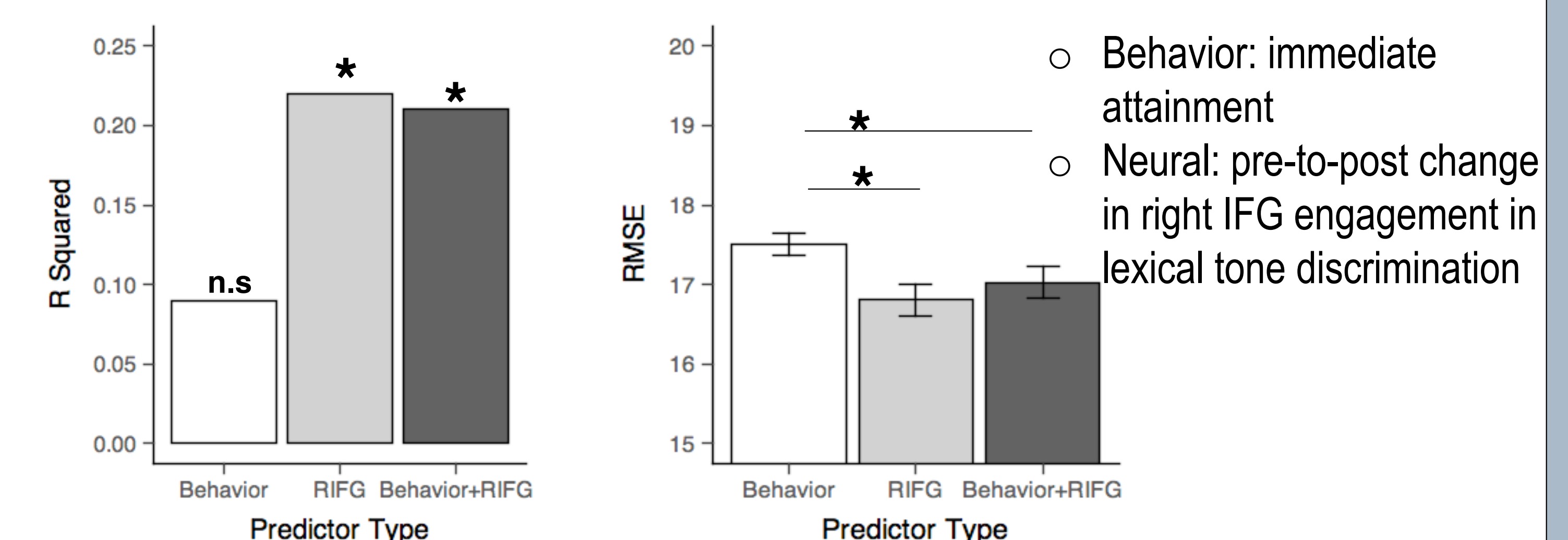
Summary:
➤ The present study demonstrated how the brain organization of speech perception, a fundamental linguistic ability, has a long-lasting effect on adults' holistic acquisition of foreign language.
➤ Successful whole-language learning hinged on both initial engagement and subsequent disengagement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

Reference:
[1]. Sebastián-Gallés N, Díaz B (2012) Lang Learn, 62:131–147.
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[3]. Chandrasekaran B, Sampath PD, Wong PCM (2010) J Acoust Soc Am 128:456–465.
[4]. Mueller JL, Friederici AD, Männel C (2012) Proc Natl Acad Sci U S A 109:15953–15958.
[5]. Yang J, Gates KM, Molenaar P, Li P (2014). J Neurolinguistics:1–21.