Cortical Plasticity of Sentence Processing after Classroom-Based Language Training Experience

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INTRODUCTION

» Prior lab-based research mostly focuses on training a single aspect of language.

» It is poorly understood how naturalistic training experiences affect the neural organization of sentence processing in early learners of a foreign language.

» Only one fMRI study (Barbeau et al., 2016) has investigated functional plasticity in real-world language learners. However, the sentence reading task simply relies on decoding, rather than comprehension.

» The current study investigates the functional plasticity of auditory sentence comprehension after a one-month classroom-based Mandarin course.

METHODS

Participants

Twenty-four native speakers of American English (8 females and 16 males; mean age = 23.2, SD = 3.68; mean IQ = 118, SD = 12.34). One participant was removed from the analysis due to excessive motion during the fMRI scan.
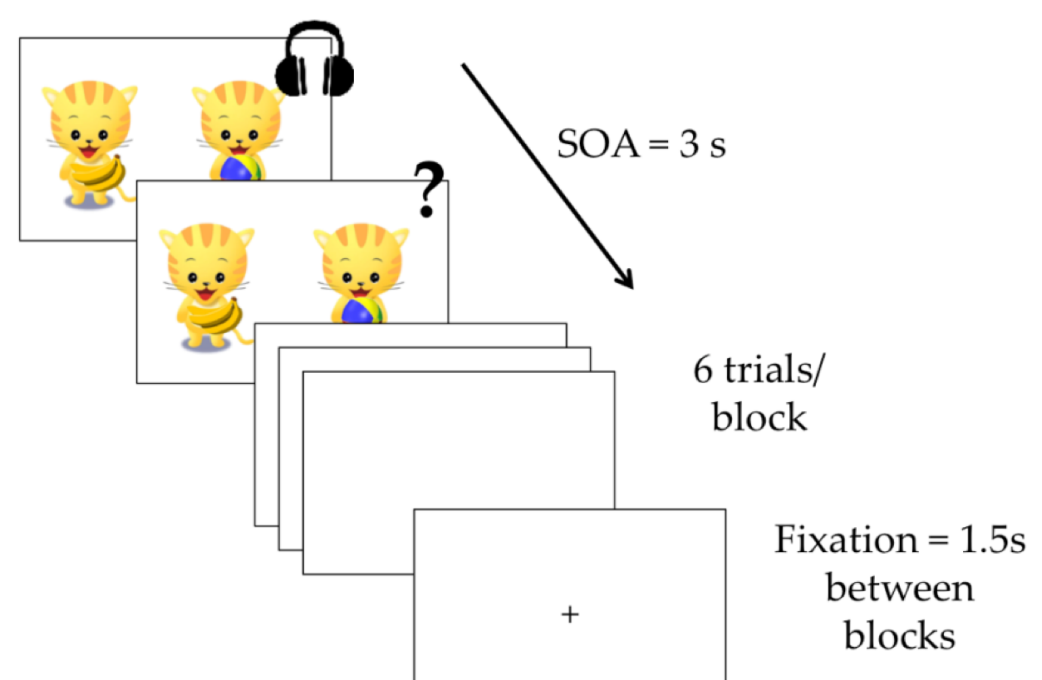
Language Training

• 3.5 hours per day, 5 days per week and 4 weeks of classroom-based Mandarin course (mean total time in the classroom: 62.3 hours)
• 11 assignments (2.7 hours per assignment), 10 quizzes, one midterm exam, and one final exam.
• Standardized proficiency test (HSK Level 1) was administered immediately after the course and again 3 months later.

Proficiency	# Subjects	Mean (SD)
Immediate Attainment	24	70.06 (10.78)
90-day Retention	19	54.76 (19.49)

fMRI Method

Sentence-Picture Matching Task

• Fifteen 6-trial blocks in one of the 3 languages in 2 runs
  • English
  • Mandarin
  • Miniature Artificial Language (MAL)
• TR = 2000ms, TE = 30ms, flip angle = 90º, voxel resolution = 3.2 × 3.2 × 3.2 mm, 191 volumes, 12.5 min.
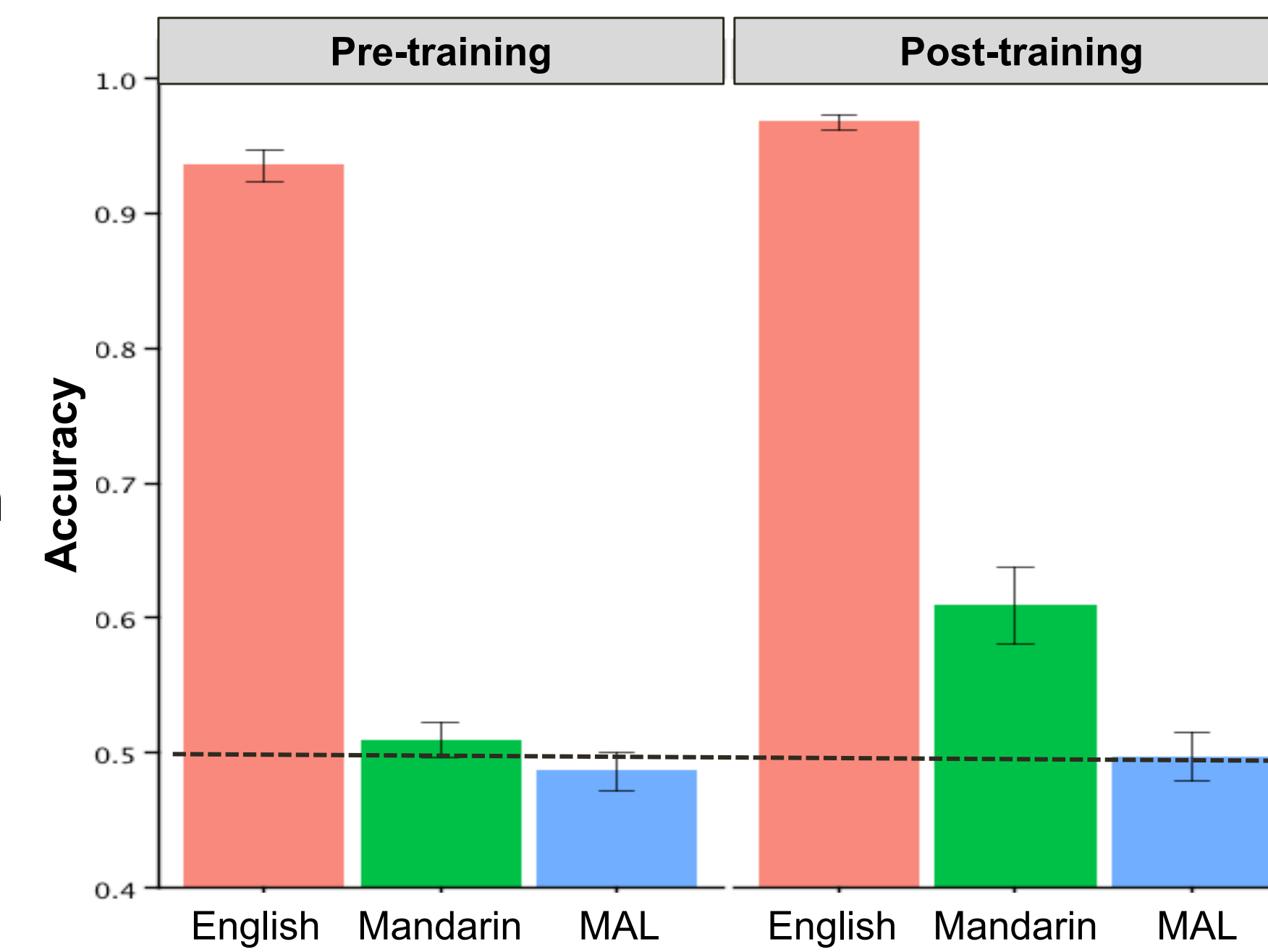• FSL v5.0.6; Freesurfer v5.3.0; Nipype v0.8; Motion < 1 mm; Intensity Z < 3
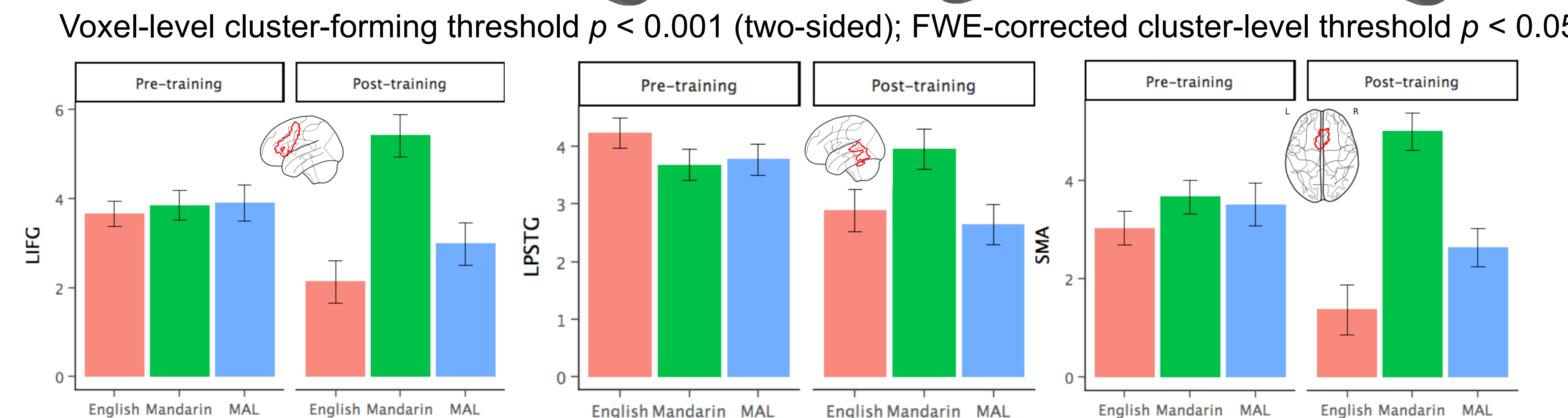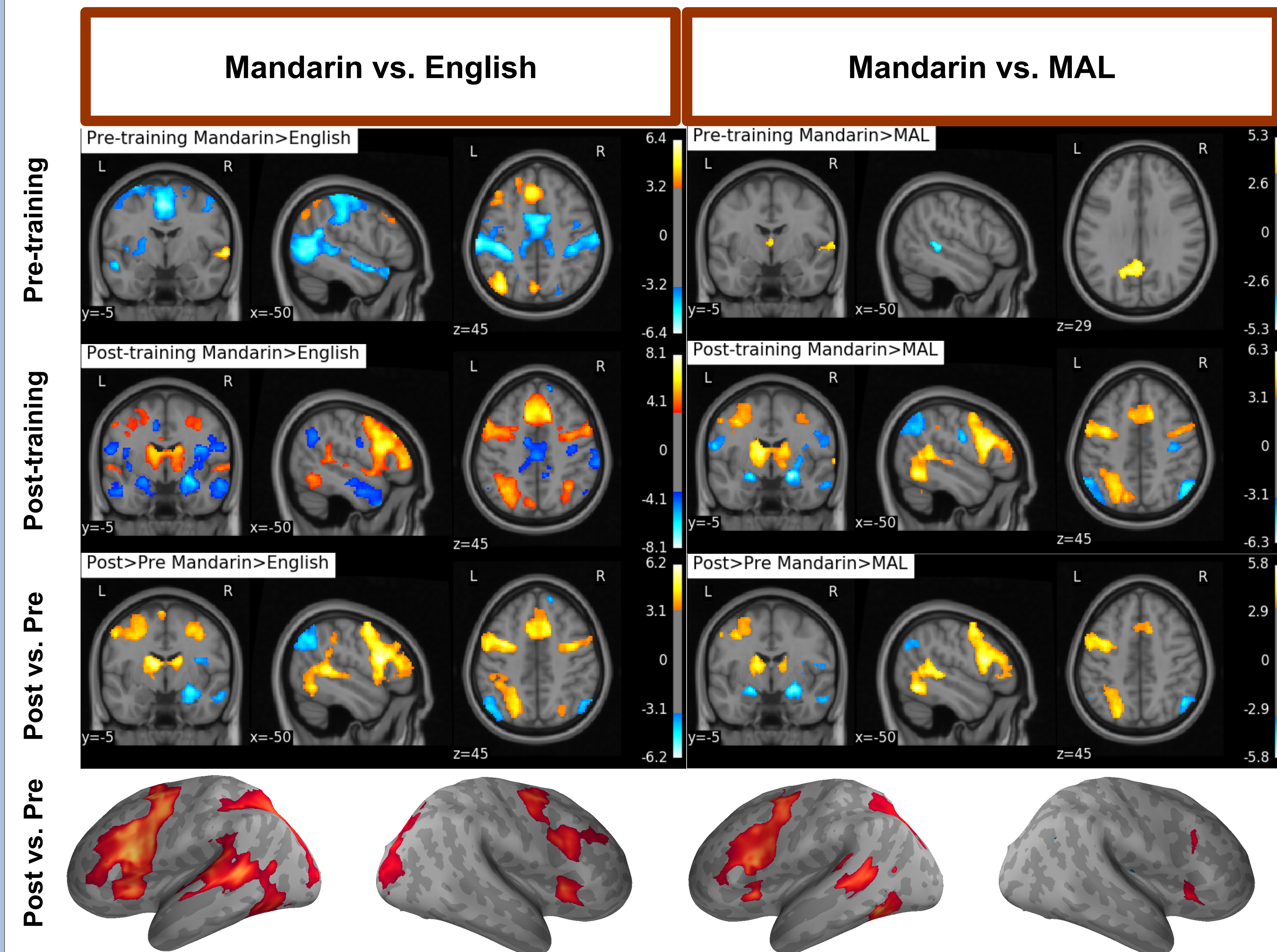
RESULTS

Behavioral Results

◆ Significant Main Effect of Language
  ◆ $F_{(2,46)} = 520.1$, $p < .001$
◆ Significant Main Effect of Session
  ◆ $F_{(1,23)} = 14.94$, $p < .001$
◆ Significant interaction between Language and Session
  ◆ $F_{(2,46)} = 5.46$, $p < .01$
◆ Significantly greater increase in accuracy in Mandarin than in English or in MAL
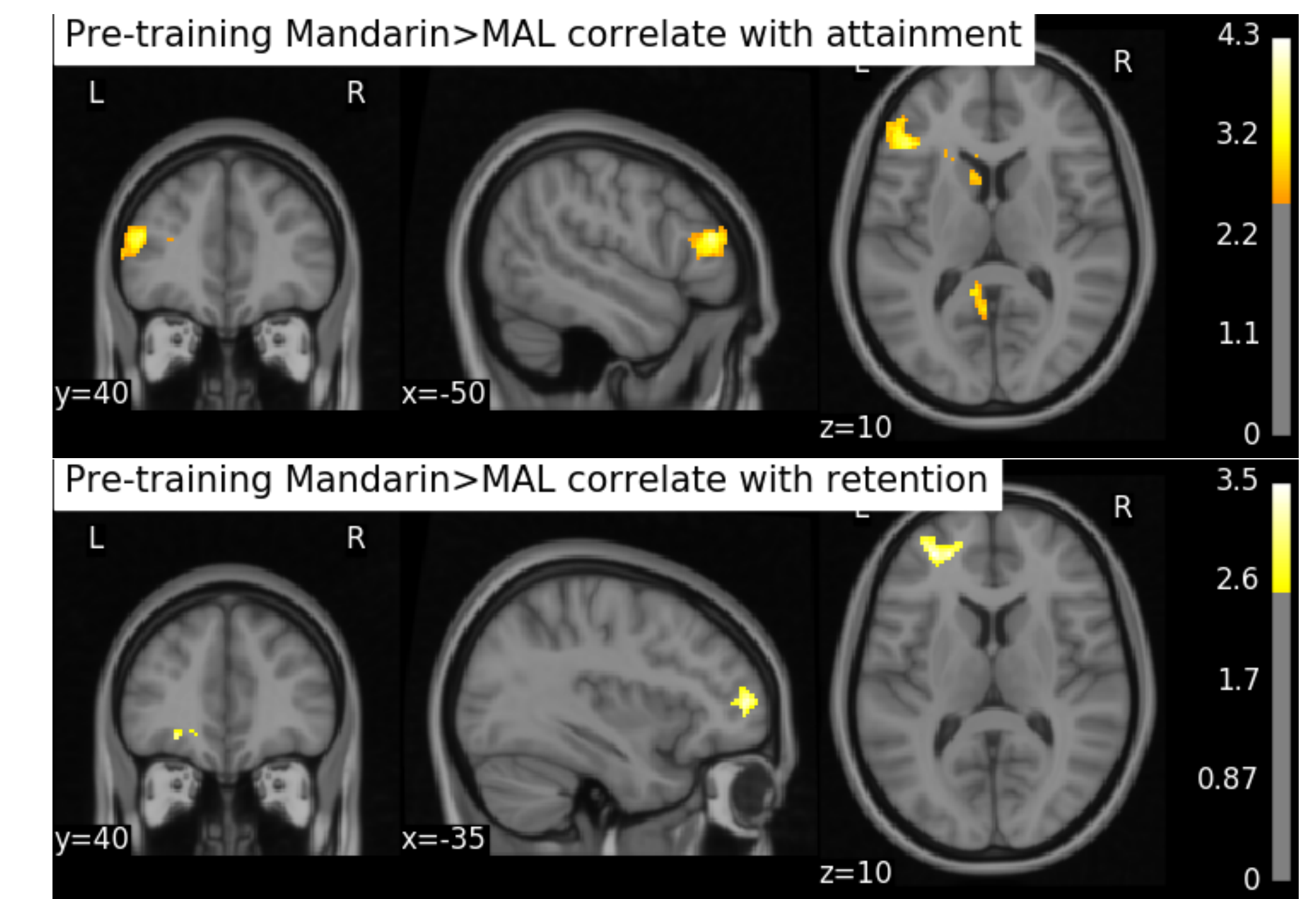 ◆ F's $_{(1,23)} > 6.8$, p's $< .02$

fMRI Results

Voxel-level cluster-forming threshold $p < 0.001$ (two-sided); FWE-corrected cluster-level threshold $p < 0.05$.

RESULTS

Brain-Proficiency Correlation

Voxel-level cluster-forming threshold $p < 0.005$; FWE-corrected cluster-level threshold $p < 0.05$.

SUMMARY

A. Functional Plasticity of L2 Sentence Processing

1. After training, compared to English and MAL, the Mandarin condition elicited greater increases in
   • the activation in left IFG, left pSTG, and SMA;
   • the activation in the frontal-parietal network;
   • the deactivation of DMN and bilateral hippocampi.
2. These changes represent effortful sentence processing in early learners:
   • extra recruitment of the prefrontal and speech-motor networks;
   • deficient activation in left STS.

B. Initial left IFG activation in response to Mandarin is associated with future learning success: both immediate attainment and long-term retention 3 months later, consistent with prior studies in structural MRI and resting-state fMRI (Flöel et al., 2009; Ventura-Campos et al., 2013; Chai et al., 2016).

C. Mandarin elicited greater activation in the right STG compared to either English or MAL, which also follows the phonotactic rules of English.

D. Future directions:
   • Are these neural signatures of language learning specific to Mandarin?
   • What are the computational differences between fluent L1 sentence processing and effortful but erroneous L2 sentence processing?

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