Brain-behavior relationships in implicit learning of non-native phonetic categories

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Introduction

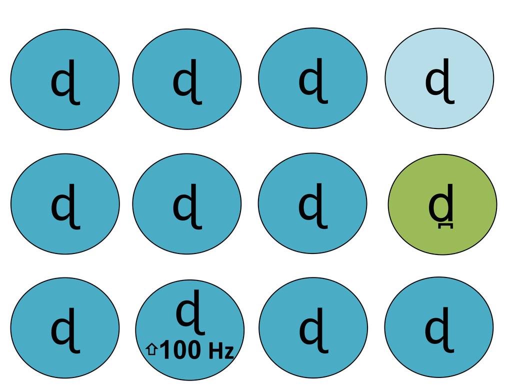
- Success in phonetic learning is highly variable among adult learners[1,3]
- Previous studies using explicit training paradigms have found:
  - Bilateral middle frontal gyri (MFG) and left inferior frontal gyrus (LIFG) are recruited in processing non-native category differences[3]
  - Learning is associated with less activation in LIFG and more activation in bilateral angular gyri[1]
- Given claims that frontal recruitment in sound processing reflects mapping to explicit labels[2], we investigate:
  (1) whether frontal regions are involved in processing non-native categories that have been *implicitly* learned, and
  (2) whether there is a reduction of activation in frontal areas after implicit training.

Methods

Day 1	Day 2	Day 3	Day 4
fMRI scan 1 DTI scan Implicit behavioral training	Implicit behavioral training	Implicit behavioral training	fMRI scan 2 Assessments: ID and AX

Participants (native English speakers, n = 18) implicitly trained on non-native Hindi dental/retroflex contrast

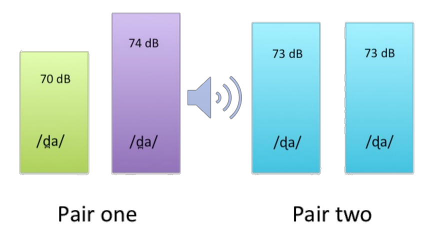
fMRI Design: Short-Interval Habituation



Implicit Training[4]

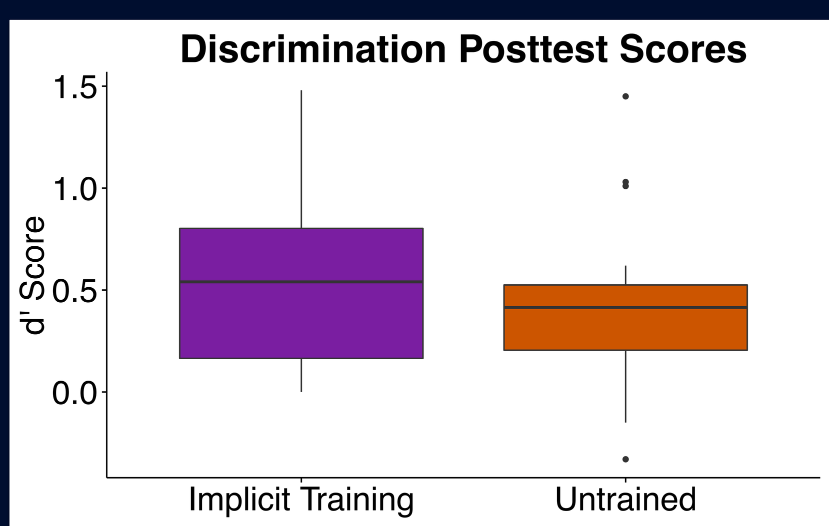
Which pair contains the volume difference?

Volume difference consistently paired with one of the two speech sounds to be learned (counterbalanced)



Trial-by-trial volume difference determined by a three-down-one-up adaptive staircase procedure

Behavioral Results



Trained participants discriminated better than a group of naïve listeners, but this difference did not reach significance.

Note the considerable variability among subject discrimination abilities, particularly in the implicit training group.

References

[1]Golestani, N., & Zatorre, R. J. (2004). Learning new sounds of speech: reallocation of neural substrates. *Neuroimage*, *21*(2), 494-506.
[2]Hickok, G., & Poeppel, D. (2004). Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language. *Cognition*, *92*(1), 67-99.
[3]Myers, E. B., & Swan, K. (2012). Effects of category learning on neural sensitivity to non-native phonetic categories. *Journal of Cognitive Neuroscience*, *24*(8), 1695-1708.
[4]Vlahou, E. L., Protopapas, A., & Seitz, A. R. (2012). Implicit training of nonnative speech stimuli. *Journal of Experimental Psychology: General*, *141*(2), 363-381.

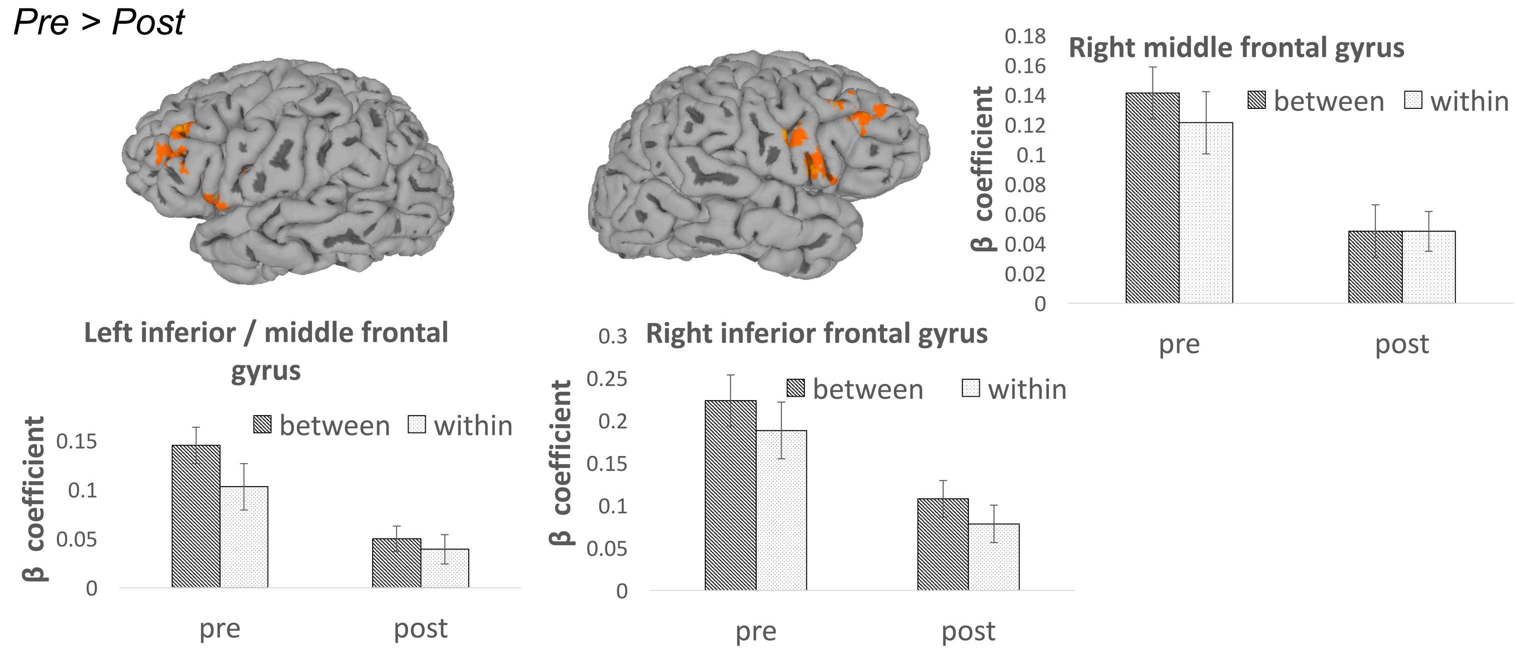
This research was supported by NIH R01 DC013064, NIH NIDCD R01 DC006220, and NSF IGERT DGE-1144399.

fMRI Results

Because of the considerable variability in learning, data were submitted to a 2x2 **Session** (Pre/Post) x **Token** (Between/Within) ANCOVA with **post-test discrimination** score as a continuous covariate.

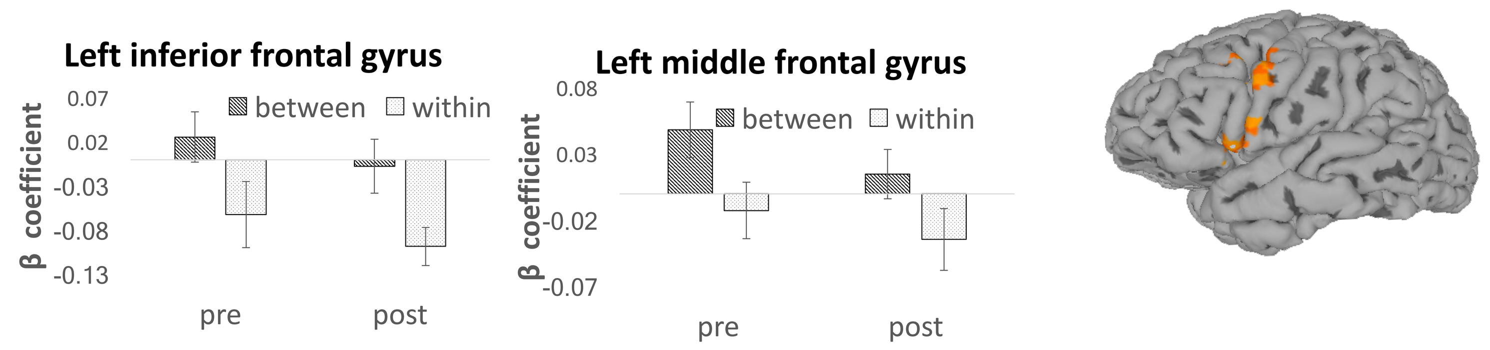
Which regions show changes in activation before vs. after training?

Pre > Post



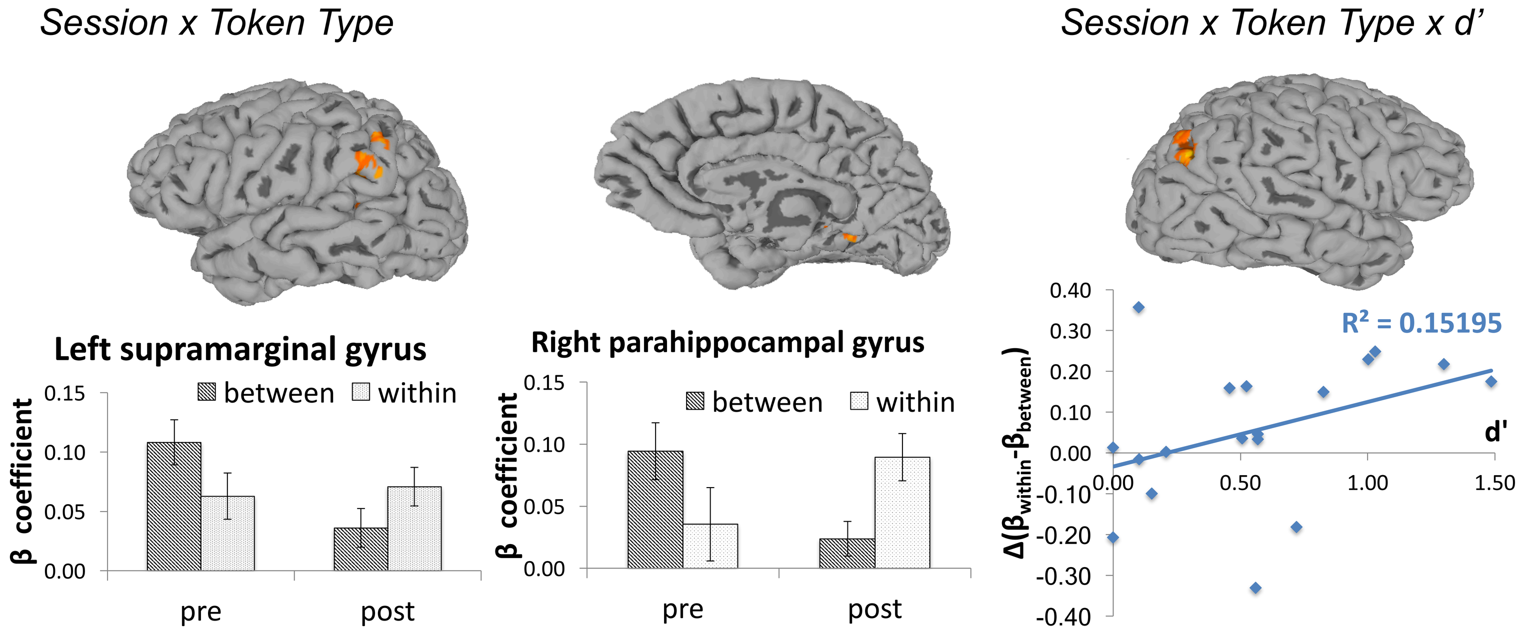
Which regions show differential sensitivity to between- vs. within-category trials?

Between > Within



How does sensitivity to the category difference change between sessions?

Session x Token Type — *Session x Token Type x d'*



Conclusions

Behavioral: Adult listeners exhibit substantial variability in how well they are able to draw on implicit cues to learn non-native speech sounds.

fMRI: Frontal regions are involved in processing non-native speech sounds even in the absence of explicit category labels, suggesting a role for these regions in perception of non-native phonetic information more generally.

fMRI: Frontal regions are sensitive to non-native phonemic distinctions before and after training, whereas temporoparietal regions are only sensitive after training. This is consistent with studies of explicit speech category learning.

fMRI/PPI: Successful non-native phonetic learning depends on the recruitment of temporoparietal regions in addition to frontal areas:

- The most successful learners recruit right temporoparietal regions in addition to left structures
- Success in post-training discrimination was also associated with greater functional connectivity between left frontal and temporoparietal regions.

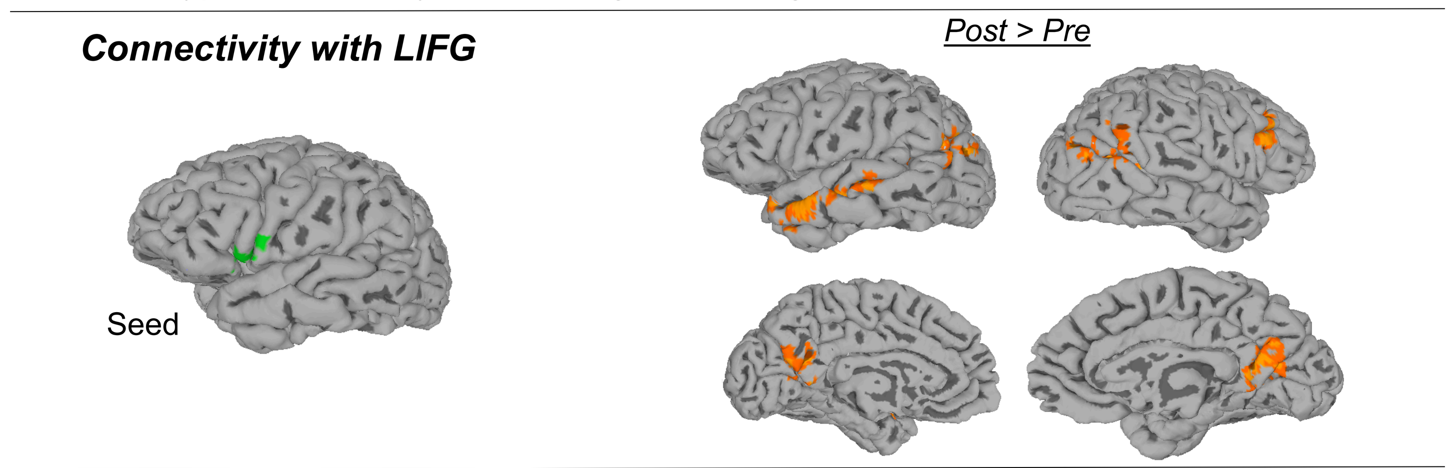
DTI: We speculate that reduced integrity of white matter tracts between frontal and subcortical areas may result in greater reliance on temporal regions associated with sensory processing, thereby facilitating learning.

PPI (Functional Connectivity) Results

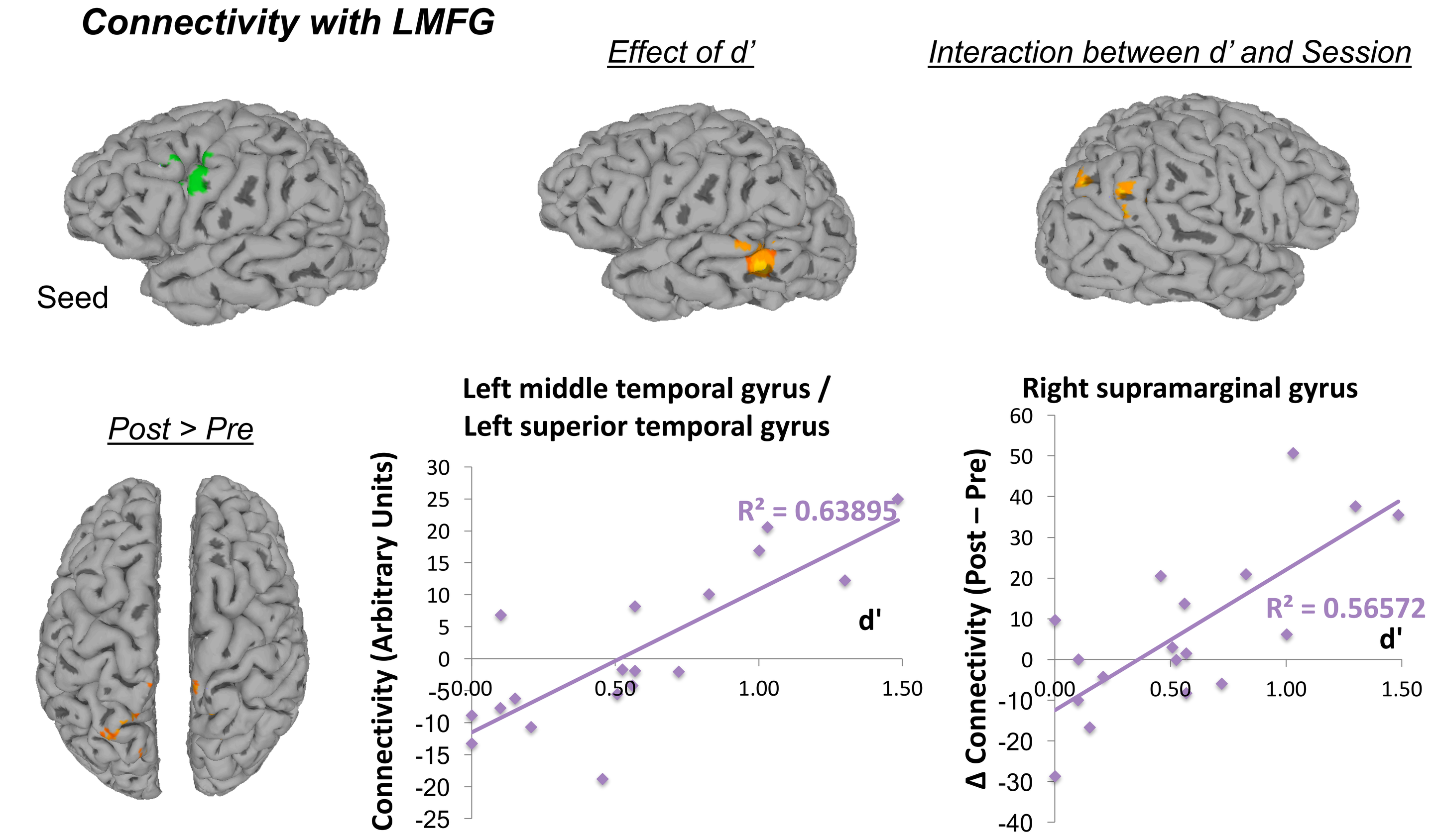
How do functional connections between brain regions differ over time and across individuals?

A gPPI analysis examined how correlations between activity in regions sensitive to Token Type and activity in other regions changed as a function of Session and/or d'.

Connectivity with LIFG



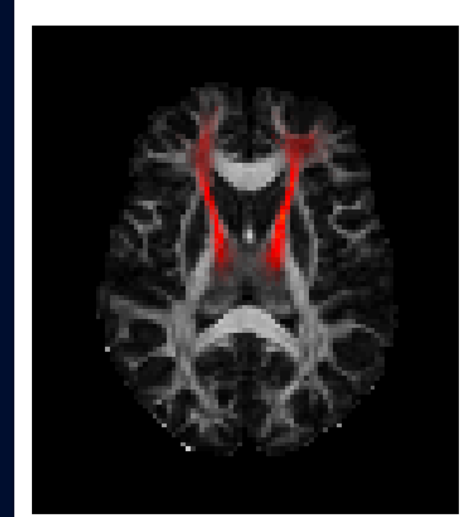
Connectivity with LMFG



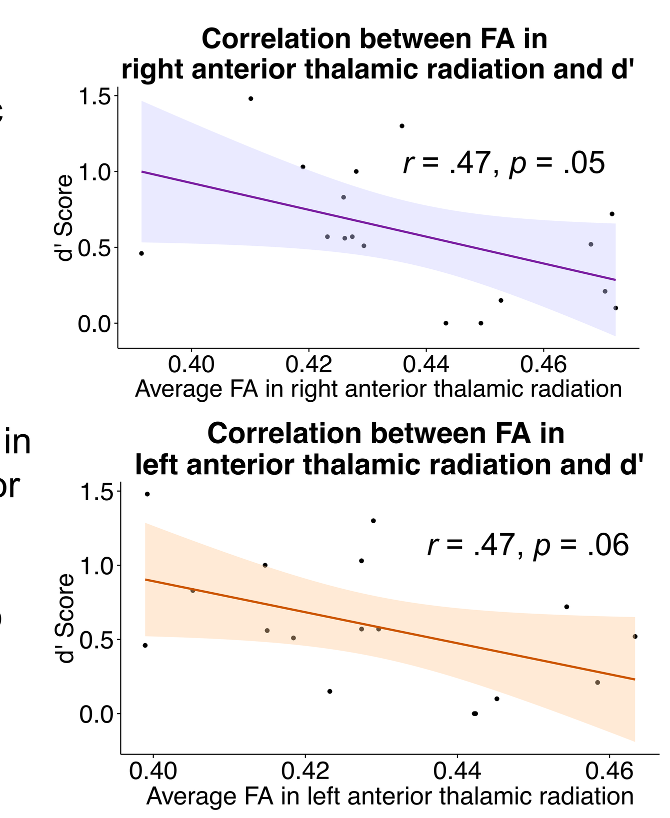
DTI Results

Do anatomical connections predict post-training sensitivity to non-native phonetic categories?

Whole-brain analysis

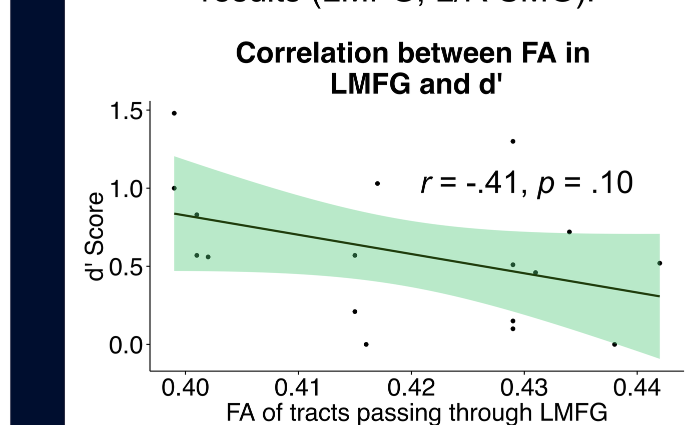


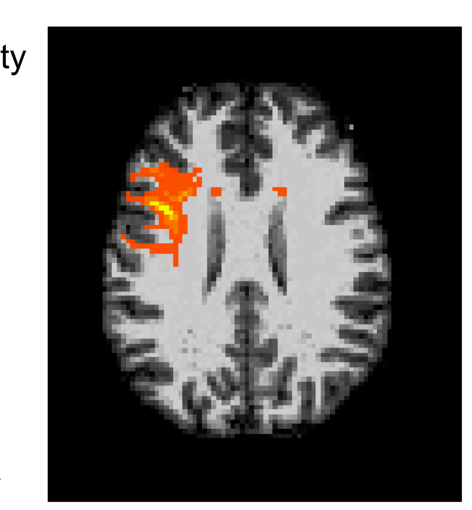
Reduced fractional anisotropy (FA) in bilateral anterior thalamic radiations was related to better post-training discrimination scores.



ROI analysis

Targets taken from functional connectivity results (LMFG, L/R SMG).





FA of tracts passing through LMFG was marginally related to post-training discrimination scores. No relationships were found with DTI metrics for L/R SMG.

n = 17 for DTI analyses