# Neural responses during procedural memory tasks are related to foreign language learning outcomes

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## Summary

Do neural systems for procedural memory contribute to foreign language learning in adults? Before in-lab or in-classroom language learning experiences, **fMRI activation measured in procedural learning areas during serial reaction time tasks was correlated with foreign language learning outcomes.** These results provide preliminary evidence that the function of neural systems for procedural memory[1,2,4,5] may contribute to individual differences in foreign language learning abilities.

## Methods

### Participants

Laboratory group: Native English speakers (N=42); 23±3 years; all right-handed; all monolingual (with < 4 years classroom L2).

Classroom group: Native English speakers (N=24); 23±4 years; 20 right-handed; 19 monolingual; no prior Chinese experience.

### Language training

The laboratory group completed 4 days of computer-based training on a miniature artificial language[1] comprising new grammar and vocabulary. The classroom group completed a 4-week Mandarin training course using the 新实用汉语课本 [3].

### In-scanner task

In a serial reaction time task[2,5], participants responded to a circle that appeared in four spatial locations. Participants' procedural learning was measured under two conditions relative to a random order baseline: serial, with the location order always within {231432413421}, and transformed, in which participants responded to the adjacent location (e.g., {14232} → {21343}).

### fMRI acquisition

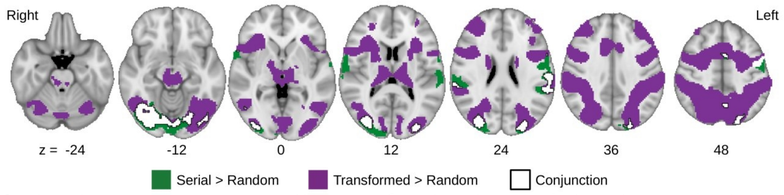
Siemens Trio 3T; 32ch coil; Structural: T1 ME-MPRAGE, 1mm$^3$; Functional: T2* EPI, TR=2.0s; 3.2mm$^3$; 31 slices, whole-brain.

### fMRI analysis[6]

Preprocessing: boundary-based registration to anatomy, motion and slice-time correction, spatial filtering (6mm FWHM, by tissue type), nonlinear normalization to MNI template.

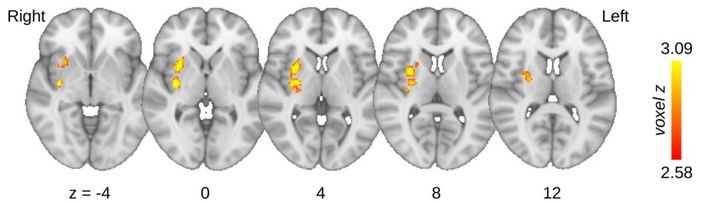
Modeling: GLM with task (random, serial, transformed) and nuisance (motion, global brain & WM PCA, and outliers) factors; fixed-effects within subjects, mixed-effects between subjects.

## In the laboratory



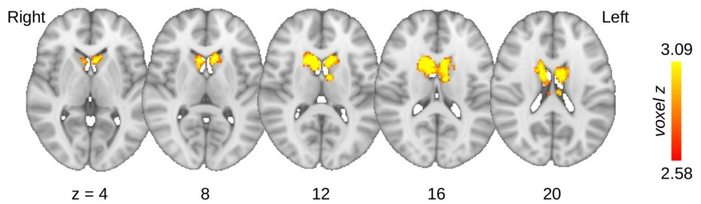

Distinct and common patterns of activation related to implicit and explicit procedural learning (voxel $p < 0.001$; cluster FWE = 0.05)

**Novel grammar acquisition ~ (serial > random)**



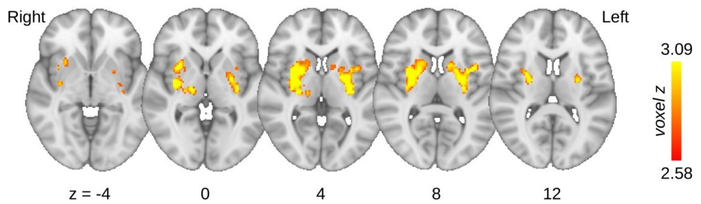

Activation during the implicit procedural learning task in right putamen before training was significantly related to future grammar learning accuracy. (voxel $p < 0.005$; cluster FWE = 0.05)

**Novel vocabulary acquisition ~ (transformed > random)**



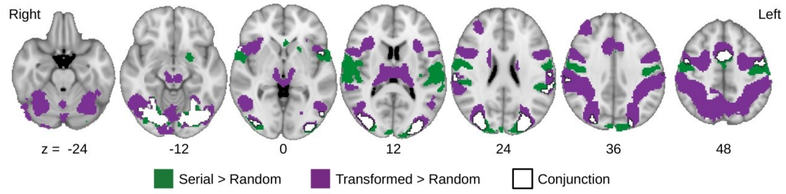

Activation during the explicit procedural learning task in bilateral caudate before training was significantly related to future vocabulary learning accuracy. (voxel $p < 0.005$; cluster FWE = 0.05)

**Novel grammar retention (3 month) ~ (serial > random)**



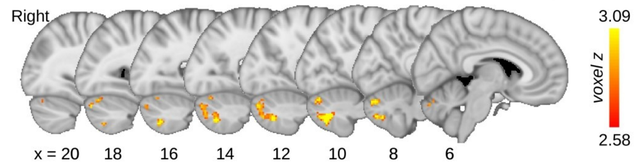

Activation during the implicit procedural learning task in bilateral putamen before training was significantly related to long-term retention of the novel grammar. (voxel $p < 0.005$; cluster FWE = 0.05)

## In the classroom

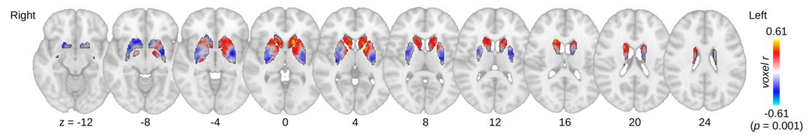



Task-selective activation to implicit or explicit procedural learning tasks was identical across groups. (voxel $p < 0.001$; cluster FWE = 0.05)

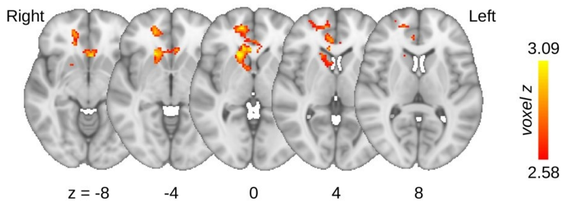
**Holistic Mandarin attainment ~ (serial > random)**




Activation during implicit procedural learning in right cerebellum before training was significantly related to Mandarin learning, but was not significant in in basal ganglia. (voxel $p < 0.005$; cluster FWE = 0.05)




**Holistic Mandarin attainment ~ (transformed > random)**




Activation during explicit procedural learning in right caudate before training was significantly related to Mandarin learning (in a cluster extending into MePFC). (voxel $p < 0.005$; cluster FWE = 0.05)

## References

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[5] Willingham et al. (2002). *J. Neurophys.*
[6] *FSL, FreeSurfer, Nipype, Lyman*

## Support

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