White-Matter Plasticity of Adult Language Learning

Michelle Han[1], Zhenghan Qi[1], Todd Thompson[1], Keri Garel[1], Ee San Chen[1], Anastasia Yendiki[2], and John Gabrieli[1]
[1]Massachusetts Institute of Technology, [2]MGH Institute of Health Professions

Background and Research Question

- Neural plasticity, the brain's ability to change and adapt based on inputs and stimulation, continues on into adulthood.
- Still, language learning is increasingly difficult in adulthood[1].
- Existing adult language learning studies do not include control groups to separate language-specific training effects from general training effects[2].
- During early development, certain brain regions become highly specialized to language processing[1].
- Research Question: Is adult second language learning associated with changes *within* or *beyond* the existing language network?

Methods

- Participants: The three groups did not differ significantly based on age, IQ, or gender ratio.

	Age	IQ	M:F
Language Training (14)	22.3 (2.5)	113.2 (11.1)	6:8
Active Control (14)	21.3 (2.3)	115.6 (13.0)	5:9
Passive Control (19)	22.7 (3.0)	112.9 (9,1)	8:11

- Language Training: Introductory Modern Standard Mandarin for 3.5 hours for 5 days/week over 4 weeks.
- Active Control: Multiple Object Tracking (MOT), a visual-spatial task[3], for 30-60 minutes for 5 days/week over 4 weeks.
- Passive Control: No training was completed between scans.
- Imaging: T1-weighted anatomical and diffusion-weighted images were acquired on a 3T Siemens Tim Trio scanner before and after training to measure fractional anisotropy (FA), axial diffusivity (AD), radial diffusivity (RD).

Analysis

- Pre-Processing: All images were corrected for eddy currents and motion; registered to the subject's T1 and MNI; and used to generate maps of FA, AD, and RD using the longitudinal streams on Freesurfer[4] and TRACULA[5].
- 1) Whole-brain voxel-wise analyses[6] of diffusion measures to study interaction between session (pre vs. post) and group (language-training vs. active control and vs. passive control).
- 2) Post-hoc cluster analyses of the white-matter areas common to both comparisons, the forceps minor (fminor) and left inferior longitudinal fasciculus (ILF).

Whole-brain voxel-wise analysis

A. FA, Language Training vs. Active Control   B. FA, Language Training vs. Passive Control

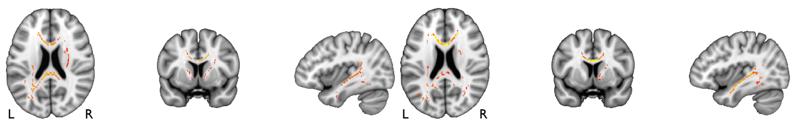

Figure 1: TBSS analysis comparing the inter-scan FA difference in the language learning group to the inter-scan FA difference in the active control group (Figure 1A) and in the the passive control group (Figure 1B).

A. RD, Language Training vs. Active Control   B. RD, Language Training vs. Passive Control

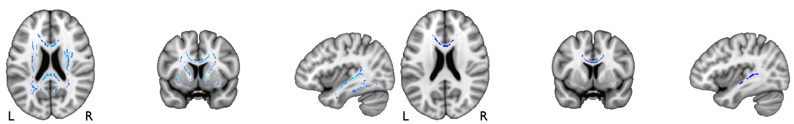

Figure 2: TBSS analysis comparing the inter-scan RD difference in the language learning group to the inter-scan RD difference in the active control group (Figure 1A) and in the the passive control group (Figure 1B).

Post-hoc cluster analysis

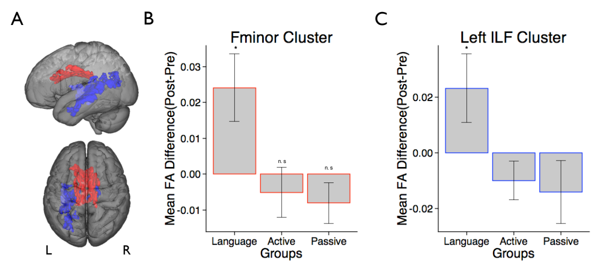

Figure 3B: FA in fminor in language (p=0.007); active control (p=0.89); passive control (p=0.27).
Figure 3C: FA in left ILF in language (p=0.004); active control (p=0.52); passive control (p=0.54).

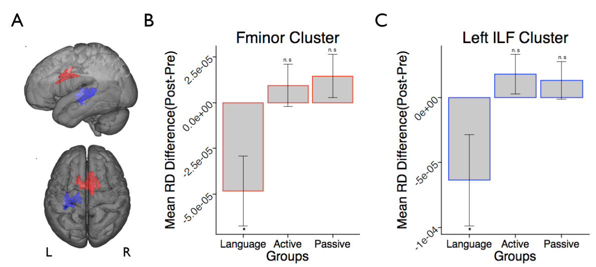

Figure 4B: RD in fminor in language (p=0.002); active control (p=0.80); passive control (p=0.38).
Figure 4C: RD in left ILF in language (p=0.014); active control (p=0.67); passive control (p=0.99).

Results

- Figure 1: The language-training group showed a significantly greater increase in FA after training than both the active control group (Figure 1A) and the passive control group (Figure 1).
- Figure 2: The language-training group showed a significantly greater decrease in RD after training than both the active control group (Figure 2A) and the passive control group (Figure 2B).
- Figure 3: Wilcox rank-sum tests showed a significant training-induced increase of FA in the language-training group, but no significant change in either the active control group or the passive control group in both fminor (Figure 3B) and left ILF (Figure 3C).
- Figure 4: Wilcox rank-sum tests showed a significant training-induced decrease of RD in the language-training group, but no significant change in either the active control group or the passive control group in both fminor (Figure 4B) and left ILF (Figure 4C).

Conclusion and Discussion

- Overall: Intensive second language acquisition in adults is associated with inter-hemispheric white matter tracts as well as left-hemisphere language related tracts.
- Results replicate 9-month Mandarin-learning study[7], which shows results are specific to language but not visual-spatial skill training.
- Increased white-matter connectivity both between hemispheres and within the left hemisphere may reflect structural adaptation for novel phonetic and orthographical categories in Mandarin[8].
- Enhanced left ILF shows may reflect the syntactic-semantic integration associated with language learning[9].
- The involvement of frontal areas may reflect increasing cognitive demand for code-switching between languages.

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Contact Information mihan@stanford.edu / zqi@mit.edu