Working Memory Filtering and Individual Differences in Second Language Aptitude

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Introduction

Individuals differ in their ability to acquire a second language (L2). Although not included in classical models (Carroll, 1962), working memory (WM) has received increasing attention as a construct that relates to L2 aptitude (Miyake & Friedman, 1998).

Prior work linking WM to L2 aptitude has taken a capacity view (Just & Capenter, 1992); however, recent research suggests that a precursor to capacity is the ability to "control access" to WM by blocking task-irrelevant information (McNab & Klingberg, 2008; Vogel, McCullough, & Machizawa, 2005).

In the present study we adopt a "control access" view of WM, and investigate whether L2 aptitude is reliant on the ability to flexibly filter out task-irrelevant stimuli.

Hypothesis 1: Selective WM filtering underlies L2 aptitude; individuals who are better at filtering irrelevant information from WM ("good" filterers) are better L2 learners than "poor" filterers.

Hypothesis 2: The ability to filter out task-irrelevant information is supported by fronto-striatal circuit functioning.

Methods

An fMRI study of WM filtering was conducted using a verbal WM task (Figure 1; modeled after McNab & Klingberg, 2008).

Following the MRI, participants completed:

- Eight 30-minute French language learning sessions using a virtual immersion software (Prat et al., 2016)
- A French post-test containing vocabulary and grammar questions

Participants

- Monolingual English speakers (N = 34, 22 female)
- Ages 18-34 (M = 20.47)
- Right-handed

Imaging Analyses

Images were corrected for slice acquisition timing, motion-corrected, normalized, co-registered, and smoothed to decrease spatial noise. Statistical analyses were performed using the general linear model in SPM8. Contrasts of interest were correlated with post-test scores.

fMRI Procedures

- **Instruction**: Filter (CATEGORY NAME) or No-Filter (WORDS)
- **Trials**: Words presented one at a time on a 3 x 3 grid
- **Probe**: Does the order and location of the probe match one of the previously presented trials? (Y/N)
- **Design**: 2(Filter vs. No-Filter) x 2(3 vs. 5 items)

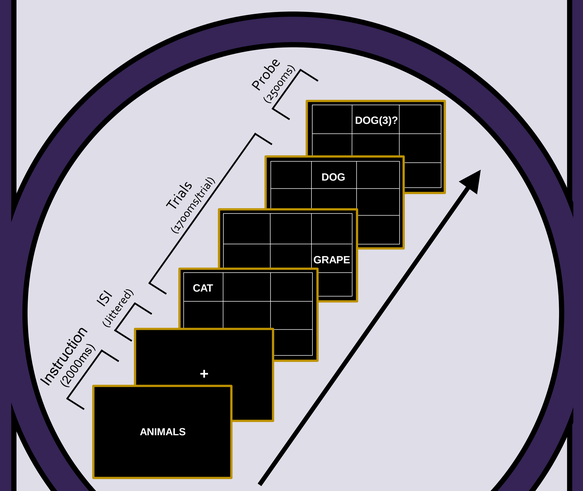

Figure 1. Example of an incorrect Filter 3 trial

	Filter 3	No-Filter 3	Filter 5	No-Filter 5
Number of Targets	2	3	3	5
Number of Distractors	1	0	2	0

Task Filtering A: Filter 3, No-Filter 3
Task Filtering B: Filter 5, No-Filter 5

Critical fMRI Contrasts:

- **Instruction Activity:** Preparatory activity is indexed by the *difference* in activation between Filter and No-Filter conditions during the instruction phase.
- **Task Filtering A:** Better filtering is indexed by a *smaller* difference in activation between Filter 5 and No-Filter 3.
- **Task Filtering B:** Better filtering is indexed by a *larger* difference in activation between No-Filter 5 and Filter 5.

Results

Behavioral Task Accuracy:

	Filter	No-Filter
3 Items	M = 0.92 (SD = 0.11)	M = 0.91 (SD = 0.13)
5 Items	M = 0.88 (SD = 0.12)	M = 0.85 (SD = 0.12)
Total	M = 0.90 (SD = 0.09)	M = 0.88 (SD = 0.10)

Instruction Phase fMRI Activity:

- *Less* preparatory activity in bilateral medial temporal regions predicted higher vocabulary post-test performance (Figure 2).
- *More* preparatory activity in bilateral parietal and right fronto-temporal regions predicted higher grammar post-test performance (Figure 2).

Task fMRI Activity:

- Task Filtering A: Better filtering, as indexed by *smaller* differences in activation between Filter 5 and No-Filter 3 conditions in left DLPFC, predicted higher vocabulary post-test performance (Figure 3).
- Task Filtering B: Better filtering, as indexed by *larger* differences in activation between No-Filter 5 and Filter 5 in left DLPFC, left parietal lobe, and ACC, predicted higher vocabulary post-test performance. *Larger* activation differences in ACC also predicted higher grammar post-test performance (Figure 3).

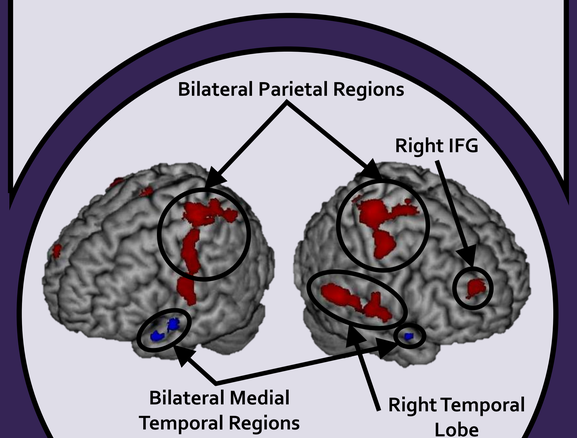

Figure 2. Activation map showing a *positive* correlation between the contrast of Filter > No-Filter instructions and post-test **grammar** scores and a *negative* correlation between the same contrast and post-test **vocabulary** scores.

Results

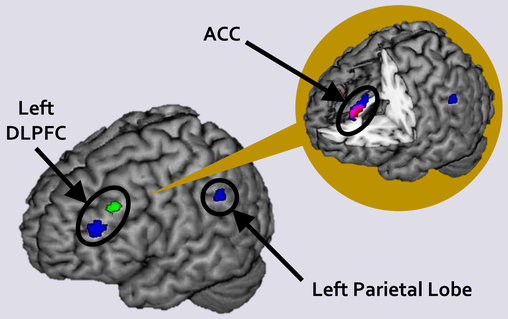

Figure 3. Activation map correlating Task Filtering Activity A with **vocabulary** post-test scores, and correlating Task Filtering Activity B with **grammar** and **vocabulary** post-test scores. Both correlations suggest that better filtering was associated with better L2 learning.

Conclusions

These results demonstrate that neural activity associated both with preparing to filter (proactive control) and with successful filtering in a verbal WM task predict L2 acquisition.

These results support **Hypothesis 1** as better filterers were also better language learners. **Hypothesis 2** was partially supported, as better filtering was indexed by activation differences in the prefrontal cortex; however, differences in striatal activation did not relate to language learning. Future work using Dynamic Causal Modeling may illuminate whether striatal activation drives prefrontal activation (e.g., O'Reilly & Frank, 2006).

Taken together, these results provide evidence that "controlling access" to WM predicts L2 acquisition, and may therefore be an important component of L2 aptitude.

References

Carroll, J. B., & Glaser, R. (1962). The prediction of success in intensive foreign language training. In *Training Research and Education*. Pittsburgh, PA: University of Pittsburgh Press.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*(1), 122-149.

McNab, F., & Klingberg, T. (2008). Prefrontal cortex and basal ganglia control access to working memory. *Nature Neuroscience, 11*(1), 103-107.

Miyake, A., & Friedman, N. P. (1998). Individual differences in second language proficiency: Working memory as language aptitude. In A.F. Healy, & L.E. Bourne (Eds.), *Foreign Language Learning: Psycholinguistic Studies on Training and Retention* (pp. 339-364). Mahwah, NJ: Lawrence Erlbaum Associates.

O'Reilly, R. C., & Frank, M. J. (2006). Making working memory work: A computational model of learning in the prefrontal cortex and basal ganglia. *Neural Computation, 18*(2), 283-328.

Prat, C. S., Yamasaki, B. L., Kluender, R. A., & Stocco, A. (2016). Resting-state qEEG predicts rate of second language learning in adults. *Brain and Language, 157-158*, 44-50.

Vogel, E. K., McCollough, A.W., & Machizawa, M.G. (2005). Neural measures reveal individual differences in controlling access to working memory. *Nature, 438*(24), 500-503.

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