Understanding the Neurocognitive Mechanisms of Maintenance and Disengagement in a Complex Working Memory Task

Malayka Mottarella[1] & Chantel S. Prat[1,2]

1. Department of Psychology, 2. Institute for Learning and Brain Sciences, University of Washington, Seattle, WA, USA

Introduction

What drives individual differences in performance on a complex working memory task?

- *Capacity View:* The amount of information individuals can maintain and/or manipulate in working memory.[1]
- *Executive Attention View:* The ability to selectively maintain only task-relevant information while disengaging attention from distracting information.[2]

How do individuals determine if information is relevant?

- *Goal Maintenance:* Is a mental representation of a task goal that guide the judgement of whether incoming information is task relevant. This is a prerequisite to successfully deploying attention, but also is working memory demanding.[3,4]

Paradigm

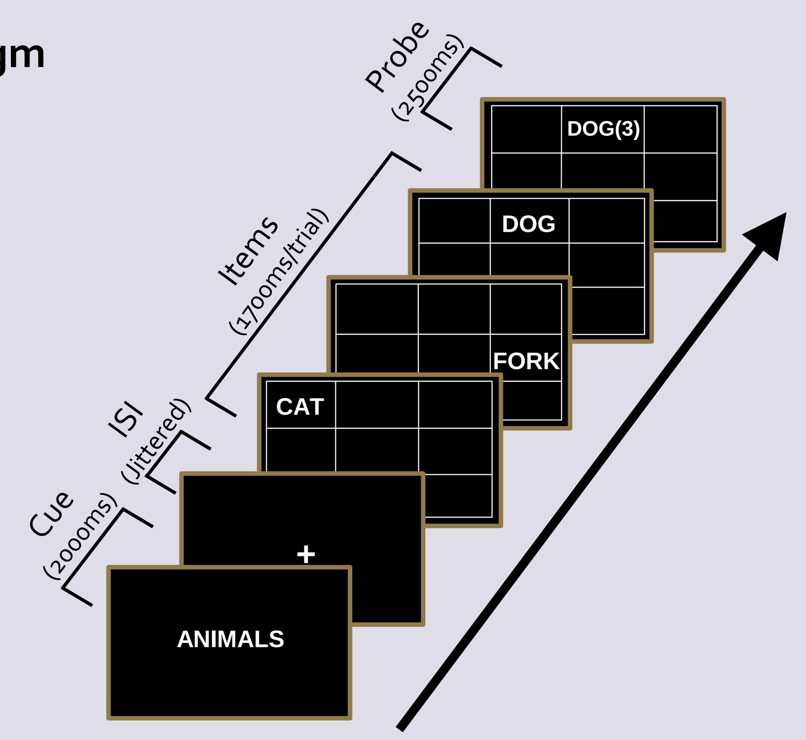

Figure 1. Example of an incorrect Filter 3 trial, where item 2 (FORK) is a distractor.

__Cue:__ Distractor-present trial(**"CATEGORY"**): only remember words in the cued category vs. distractor-absent trial (**"WORDS"**), remember all upcoming words

__Items:__ Words presented serially on a 3 x 3 grid

__Probe:__ Does the probe match the order and location of one of the targets?

Task Condition	Filter 3	No Filter 3	Filter 5	No Filter 5
Number of Targets	2	3	3	5
Number of Distractors	1	0	2	0

__Operationalizing fMRI and Behavioral Constructs:__

- *Target Load* (fMRI): No Filter 5 – No Filter 3
- *Distractor Disengagement* (fMRI): Filter 5 – No Filter 3
- *Goal Maintenance* (fMRI): Filter Cue – No Filter Cue
- *Distractor Cost* (behavioral): Filter 5 – No Filter 3 accuracy and response time differences

__Research Questions:__

1. **What are the neurocognitive mechanisms of *Target Load*, *Distractor Disengagement*, and *Goal Maintenance*?**
2. **How do individual differences in these mechanisms relate to behavioral differences in *Distractor Costs*?**

Methods

__Participants__

Data were analyzed from 71 healthy, right-handed adults. 61 had both usable scan data and behavioral accuracy above chance. Data were collected prior to participation in a larger study investigating complex skill learning.

__Whole Brain Analyses__

Statistical analysis for each task conditions was computed using the general linear model in SPM8.

__Regions of Interest (ROI) Analyses__

Beta weights and percent signal change values were extracted from bilateral striatum, prefrontal, and parietal ROIs specified a priori based on the theoretical significance of those regions in working memory (Figure 2).[5, 6, 7] Percent signal change was used to measure *Target Load* and *Distractor Disengagement*. Beta weights were used to measure *Goal Maintenance*.

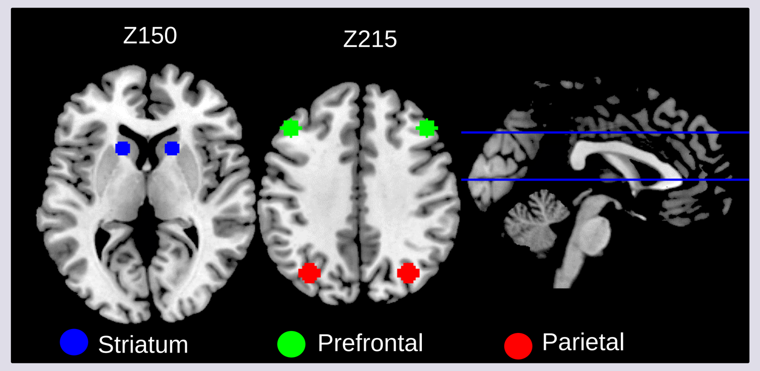

Figure 2. Depiction of bilateral ROIs

Whole Brain Results

Whole Brain Analyses revealed that the frontoparietal network was similarly active across all task conditions (Figure 3).

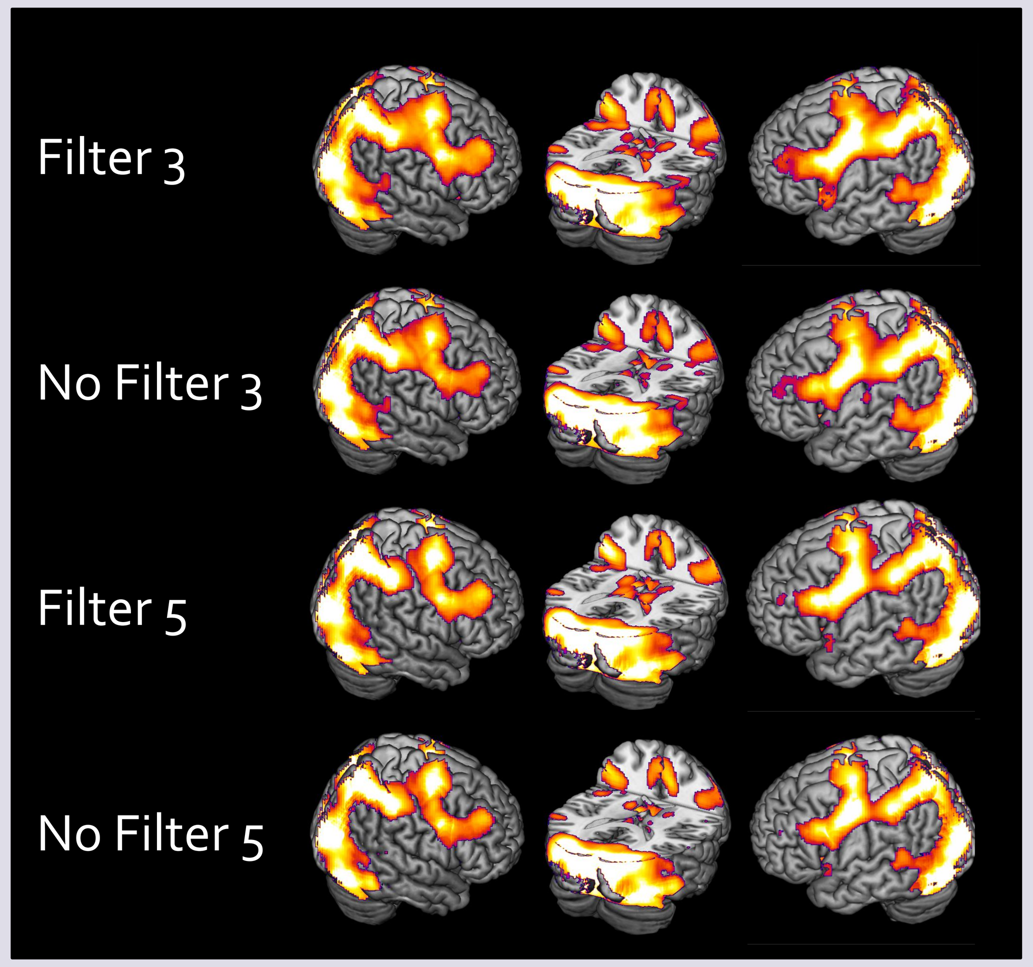

Figure 3. Group level general linear model results by task condition, p< 0.05 FWE corrected

ROI Results

__Target Load__

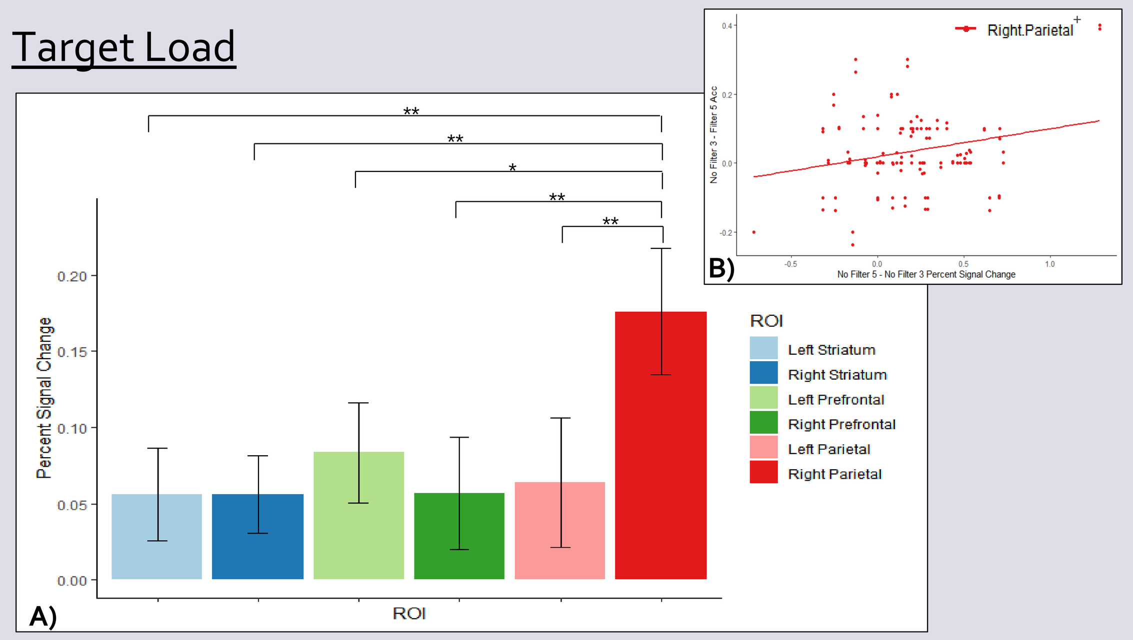

Figure 4. A) Group-level *Target Load* differences by ROI, measured using percent signal change. B) Correlation between *Target Load* percent signal change and *Distractor Cost* accuracy. +$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

__Distractor Disengagement__

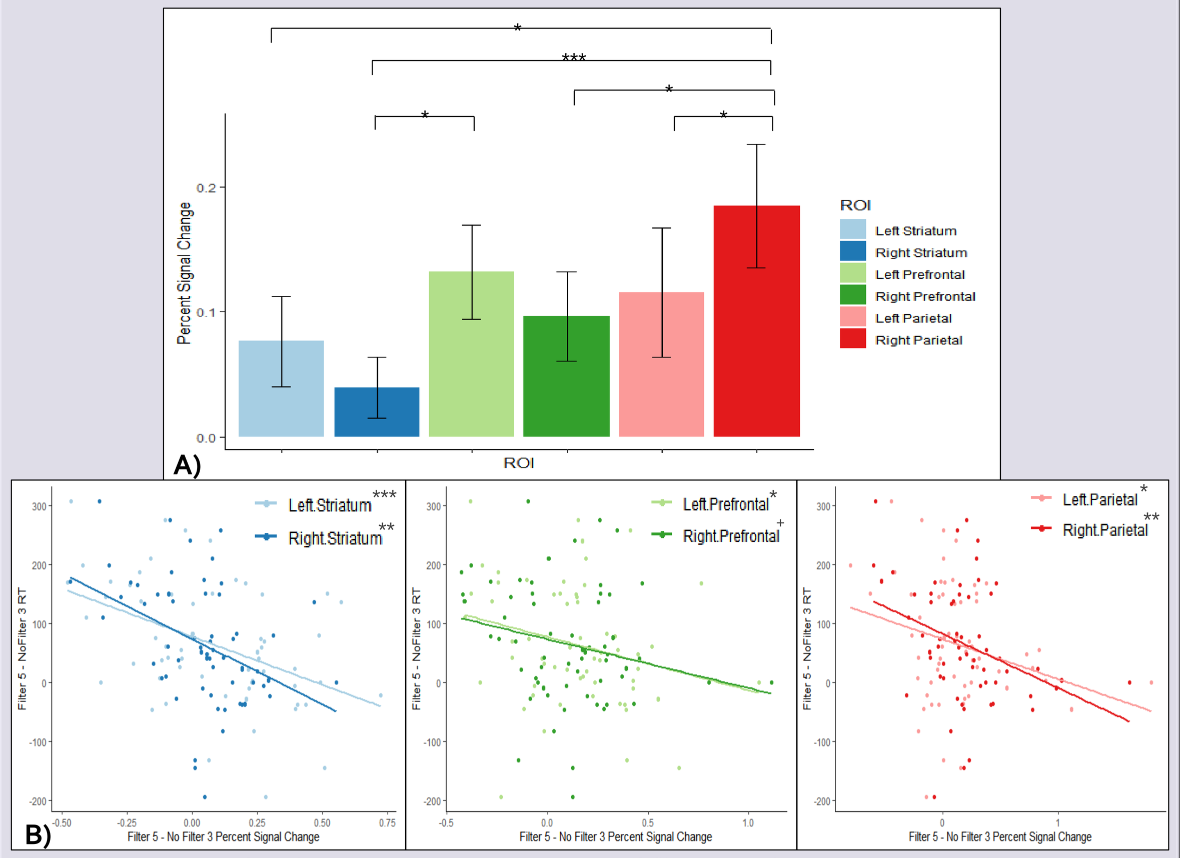

Figure 5. A) Group-level *Distractor Disengagement* differences by ROI, measured using percent signal change. B) Correlations between *Distractor Disengagement* percent signal change and *Distractor Cost* response times. +$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

__Goal Maintenance__

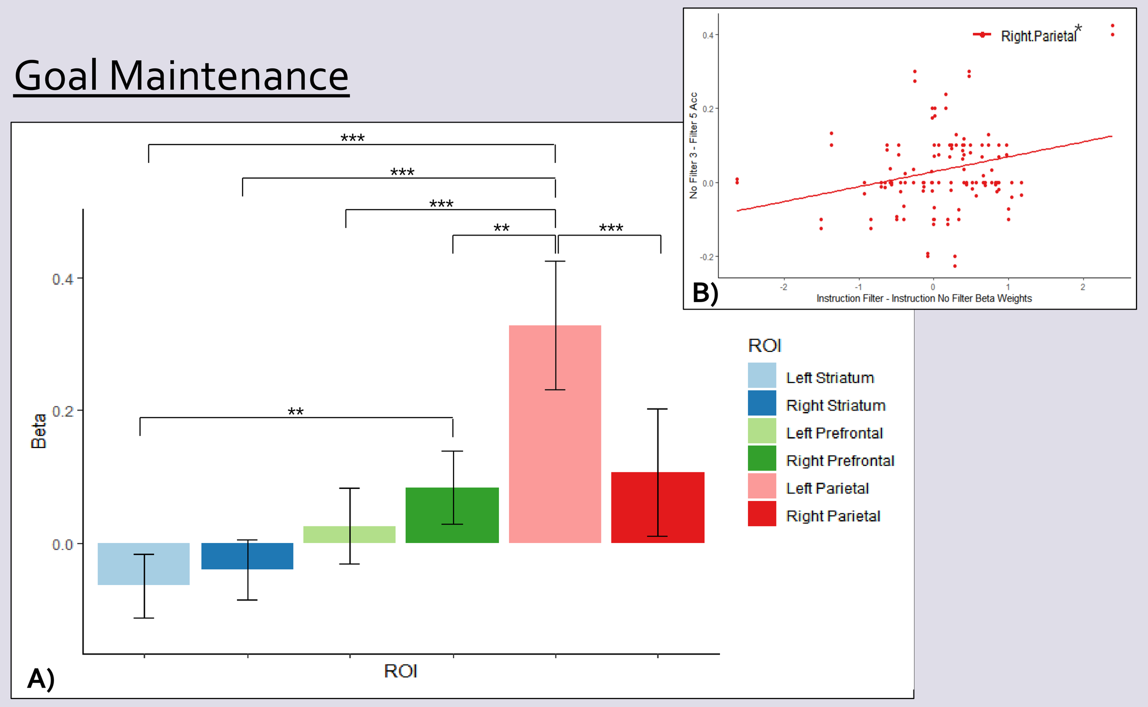

Figure 6. A) Group-level *Goal Maintenance* differences by ROI, measured using beta weights. B) Correlation between *Goal Maintenance* beta weights and *Distractor Cost* accuracy. +$p < 0.10$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Conclusions

- __Target Load__ was characterized by greater percent signal change in **right parietal** (Figure 4a). Individual differences in **right parietal** also trended towards significance as a predictor of *Distractor Cost* accuracy (Figure 4b).
- __Distractor Disengagement__ showed a similar pattern of activity to the *Target Load* condition with an additional increase in **prefrontal** and left parietal (Figure 5a). Individual differences across ROIs predicted *Distractor Cost* response times. This effect was strongest in the **striatum** (Figure 5b) which has previously been implicated as a 'gate-keeping' mechanism for working memory.[7]
- __Goal Maintenance__ was characterized by greater beta-weight fit in left parietal (Figure 6a). Individual differences in **right parietal** predicted behavioral *Distractor Cost* accuracy (Figure 6b).
- Individual differences in **right parietal** predicted behavioral *Distractor Costs* across all conditions. This is consistent with work suggesting that right parietal is important for guiding attention toward relevant stimuli and is particularly implicated in visuospatial tasks.[8]
- Left parietal activation in the *Goal Maintenance* condition may reflect initial goal encoding, whereas the *Distractor Disengagement* activity may reflect utilizing the goal to guide disengagement.
- **These results suggest distinct neurocognitive mechanisms support *Target Maintenance*, *Distractor Disengagement*, and *Goal Maintenance*, and that individual differences in these mechanisms relate to behavioral *Distractor Costs*.**
- Future directions include examining how individual differences in these mechanisms relate to established measures of working memory and attention.

References

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