# Dissociating the causal roles of frontal and parietal cortex in working memory capacity: A Registered Report

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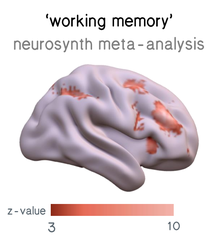
## Summary

- This peer-reviewed, pre-registered protocol will produce a publicly available dataset with fMRI, TMS, and cognitive battery data across 5+ sessions in each of 40+ participants
- In this interim sample (n= 20), TMS to frontal and superior IPS targets ***reduced WM change detection accuracy***, while inferior IPS TMS ***increased continuous report precision***.

## Motivation

Lateral prefrontal and parietal regions are widely implicated in working memory (WM)

Yet it's unclear what precise roles the regions play, and whether they are distinct




**Question:** *Do prefrontal and parietal regions causally support WM, and in what ways?*

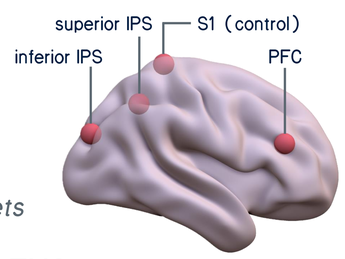
### Barriers to understanding

Most studies are correlational • Lesion studies conflict, damage is broad and variable • Brain stimulation studies use a range of protocols, parameters and targets • Many different tasks are used to test WM • Several processes may underlie any task

## Current approach

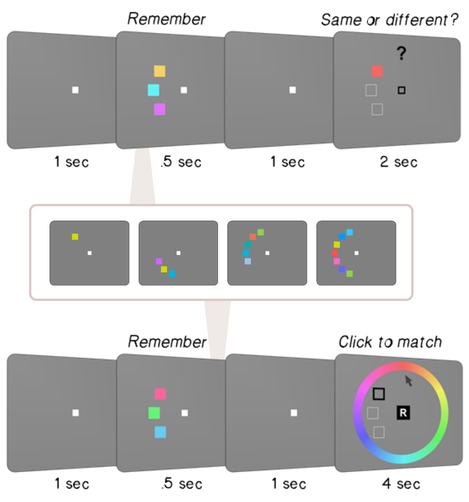
*Perturb function in nodes that are thought to be critical to WM* [1, 2]

- *Use within-subjects focal TMS to individually localized functional targets*



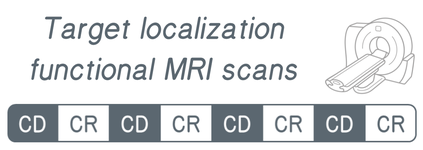

*Measure visual WM capacity after TMS*

- *Use several canonical WM tasks and fit computational models to extract nuanced aspects of behavior* [3, 4]

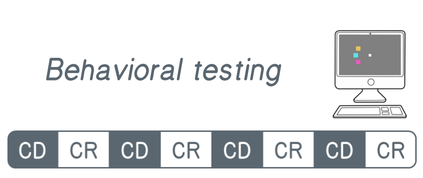



## Registered Protocol

### Day 1

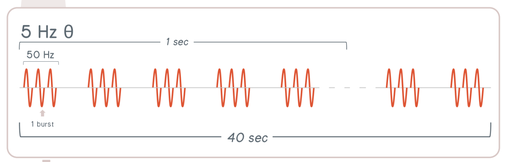




### Days 2-5

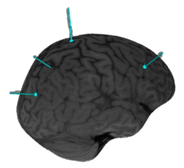

Repetitive TMS protocol

Continuous theta-burst @ 80% individual active motor threshold

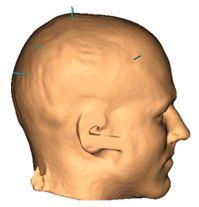



*Should reduce cortical excitability for ~1 hour*

*Counterbalanced target locations on four different days*

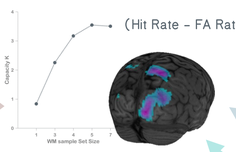


Target individual peaks with stereotaxic neuro-navigation

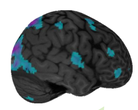


### Target selection analyses

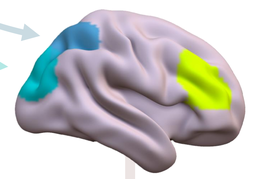
Identify voxels that parametrically track individual **Capacity $K_c$**



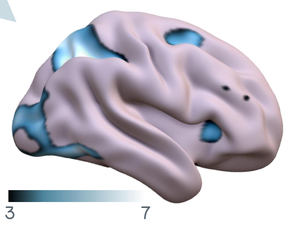

Identify voxels that respond to high **WM load** in individuals



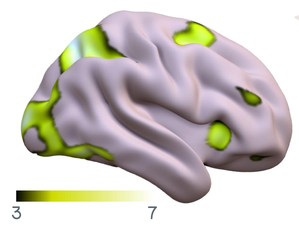
Select individual peak within each target ROI mask



***Parametric K group** effect*

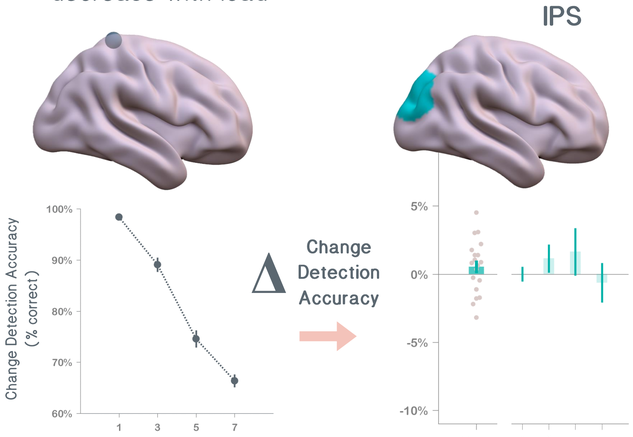



***High > low load group** effect*

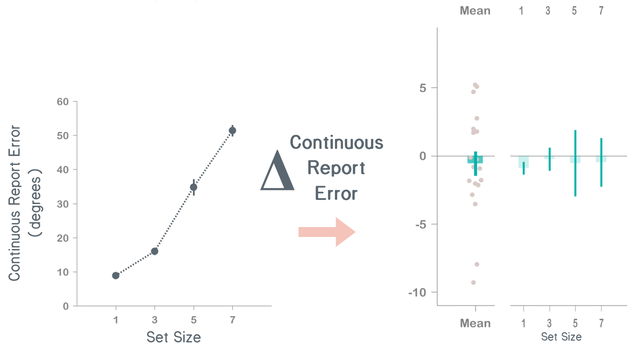



## WM behavior after TMS

*After **Control (S1) TMS**, accuracy and precision decrease with load*

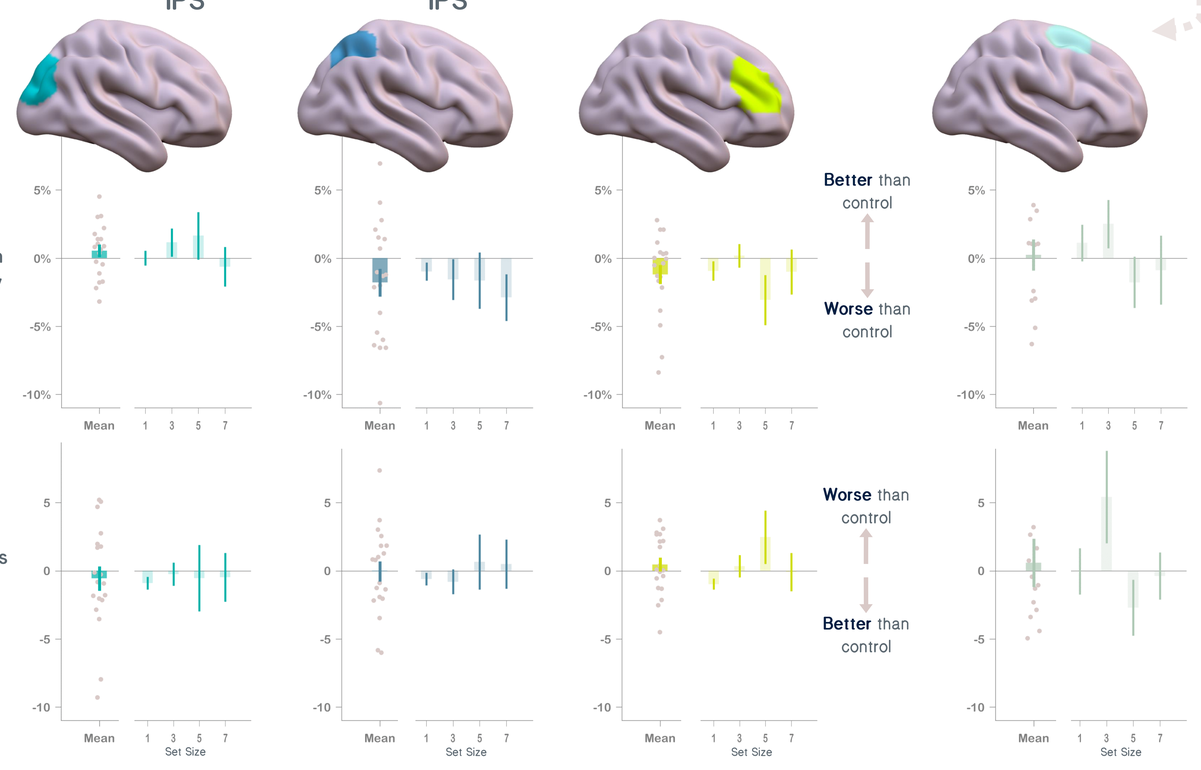



Change Detection Accuracy




Continuous Report Error

**Differences from Control**




Exploratory SFS stimulation




## Model parameter estimates

### Variable Precision model [3]

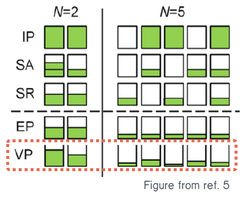
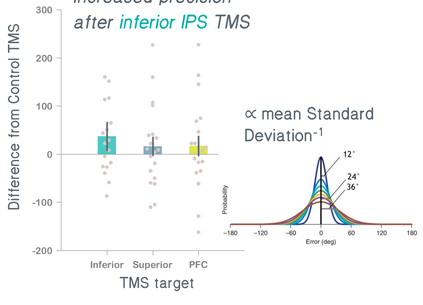



Figure from ref. 5

In the VP model, mnemonic precision is continuous and variable across all items and trials

### Mean precision $\bar{J}_1$

*Increased precision after inferior IPS TMS*

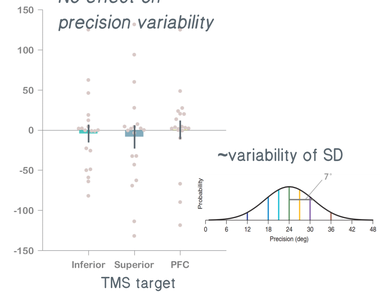






### Variability in precision $\tau$

*No effect on precision variability*

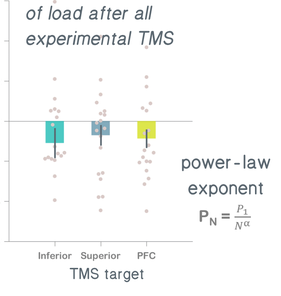






### Load Effect $\alpha$

*Reduced influence of load after all experimental TMS*



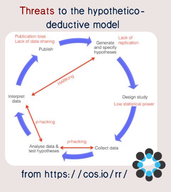

power-law exponent $P_N = \frac{P_1}{N^\alpha}$

***(Interim) Conclusion:*** *Inhibitory TMS to PFC and superior IPS regions impaired WM performance, while inferior IPS TMS improved performance; the target regions may play causal and dissociable roles in visual WM.*

## The Registered Report experience

### *What is a Registered Report?*

Study protocols and analysis plans are peer-reviewed and accepted *in-principle* before conducting study • approved plan must then be strictly followed




### *What is the point?*

To align scientific practice with ideals of scientific method, instill confidence in results • **promote** reproducible, hypothesis-driven, well-powered studies • **limit** experimenter degrees of freedom, post-hoc hypothesizing, false positive and negatives

### *What are the unique demands of the format?*

**Delineate confirmatory hypotheses:** Study must be grounded in concrete, testable predictions • proposals must detail motivation for hypotheses, how predictions will be tested, and how outcomes would be interpreted

**Demonstrate statistical power:** Sample size must be calculated *a priori* to detect smallest effect that is plausible and theoretically meaningful • power analyses should incorporate range of previous studies, consider publication bias, and match proposed hypotheses and tests

**Detail reproducible methods:** All experimental and analytical procedures, inclusion/exclusion criteria, quality checks and controls must be exhaustively described

*Practical resources for Registered Reports* https://osf.io/5gazv/wiki/

## References

**1.** Todd, J. J. & Marois, R., *Nature* **428,** 751–754 (2004) • **2.** Xu, Y. & Chun, M. M. *Nature* **440,** 91–95 (2006) • **3.** van den Berg, R., Awh, E. & Ma, W. J., *Psychol. Rev.* **121,** 124–149 (2014) • **4.** Galeano Weber, E. M., Peters, B., Hahn, T., Bledowski, C. & Fiebach, C. J., *J. Neurosci.* **36,** 5623–5635 (2016) • **5.** Keshvari S, van den Berg R, Ma WJ, *PLoS Comput Biol* 9(2): e1002927 (2013)

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Our *Nature Human Behaviour* Registered protocol https://osf.io/3pzv9/