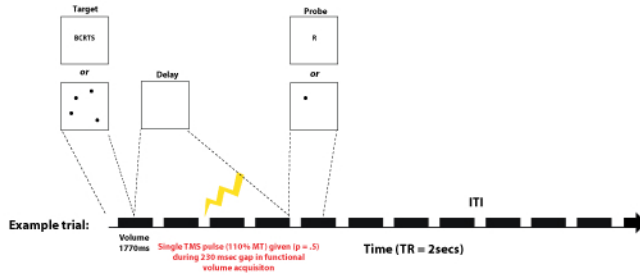


## Aims & Hypotheses

- To causally determine verbal and spatial functional networks of working memory storage.
- We used single pulse TMS to "ping" one node of a putative functional network during the delay period of a letter or spatial delayed recognition (DR) task.
- The logic was that the effects of TMS would propagate through functionally connected brain regions resulting in increased delay period activity.

## Methods

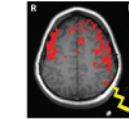
1. Session 1 fMRI: letter DR N=3; letter & spatial N=5. High- & low-load trials.
2. Functional connectivity analysis. Constrained principal component (cPCA) analysis:
  - Method for structural analysis of multivariate data (Hunter & Takane, 2002).
  - Applied to fMRI data, cPCA can identify components directly relevant to experimental conditions of interest by intergrating this information prior to computation of components.
  - Revealed letter (and spatial) load-sensitive delay period networks.
3. Session 2 TMS-fMRI: TMS delivered to a node in the storage network (or, for subjects 1-3, to a control site) during concurrent TMS-fMRI.



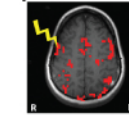
| Subject | Letter TMS Site             | Spatial TMS Site | Control TMS Site | Time between Session 1 & 2 |
|---------|-----------------------------|------------------|------------------|----------------------------|
| 1       | Left PreCG/PreCS            |                  | Left PoCG        | 17 months                  |
| 2       | Left PreCG                  |                  | Left PoCG        | 22 months                  |
| 3       | Left PreCG                  |                  | Left M1          | 17 months                  |
| 4       | Left PreCG/PreCS            | Right FEF        |                  | 1 month                    |
| 5       | Left posterior/inferior MFG | Right FEF        |                  | 1 month                    |
| 6       | Left PreCG                  | Right FEF        |                  | 1 month                    |
| 7       | Left SMG                    | Right FEF        |                  | 1 month                    |

E.g., Subject 7:

Letter node TMS



Spatial node TMS

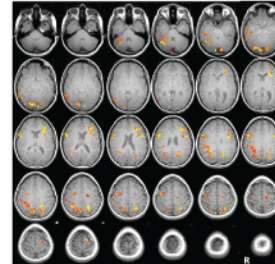


## Letter Delayed Recognition Results

- $t$ -tests comparing TMS-absent v TMS-present trials on delay period parameter estimates (averaged across all voxels with an effect of TMS > 0).

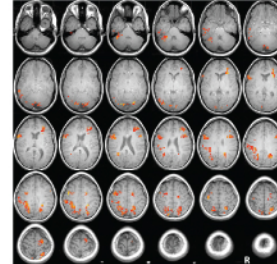
Subject 1:

Letter functional network  
Letter Site TMS



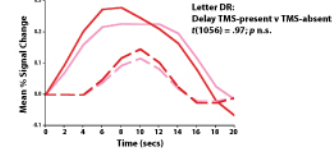
Voxels in functional network = 1441  
Voxels with increased delay period activity under TMS = 985 (68%)

Letter functional network  
Control Site TMS

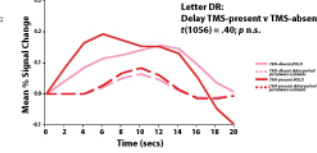


Voxels in functional network = 1441  
Voxels with increased delay period activity under TMS = 812 (56%)

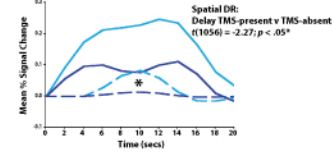
Letter Site TMS: Letter DR



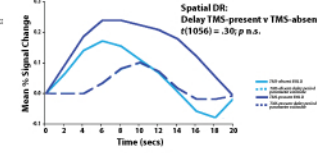
Control Site TMS: Letter DR



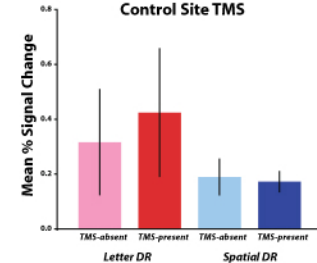
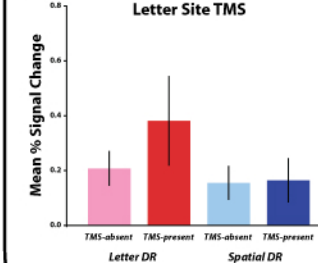
Letter Site TMS: Spatial DR



Control Site TMS: Spatial DR

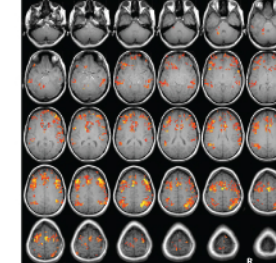


N=3:



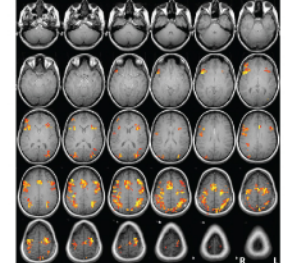
## Letter & Spatial Delayed Recognition Results

Subject 7: Letter functional network  
Letter Site TMS



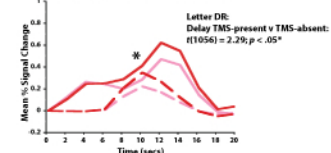
Voxels in functional network = 4674  
Voxels with increased delay period activity under TMS = 2534 (54%)

Spatial functional network  
Spatial Site TMS

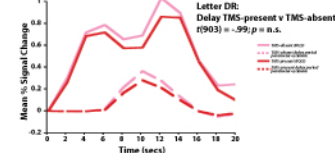


Voxels in functional network = 2346  
Voxels with increased delay period activity under TMS = 1578 (67%)

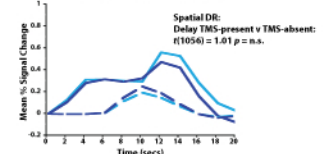
Letter Site TMS: Letter DR



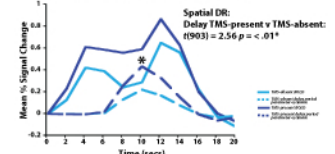
Spatial Site TMS: Letter DR



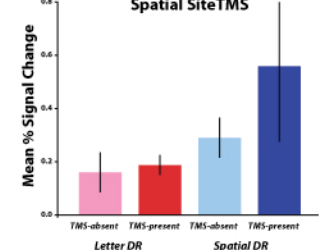
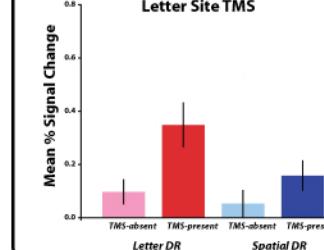
Letter Site TMS: Spatial DR



Spatial Site TMS: Spatial DR



N=4:



## Conclusions

- Neurally, verbal and spatial working memory storage are subserved by a widespread network of brain regions.
- These results suggest that one consequence of functional connectivity is facilitation of synaptic transmission between nodes in the network.

**Q: For each functional network, are there voxels showing an increase in activity as a result of TMS? If so, is the effect specific to the kind of information being retained?**