Effects of Load on Maintaining Spatial Relations vs. Locations in Working Memory

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Introduction

- **Previous work suggests that there are distinct neural systems for maintaining spatial locations vs. relations in working memory (WM)** (Ackerman & Courtney, 2012; Ikkai et al. 2014)
- **Maintaining spatial LOCATIONS in WM has been associated with increased activity in the intraparietal sulcus (IPS) and frontal eye fields (FEF)** (e.g., Silver & Kastner, 2009)
- **Maintaining spatial RELATIONS in WM has been associated with increased activity in anterior prefrontal cortex** (Ackerman & Courtney, 2012) **and medial temporal lobe regions** (Olson et al. 2006)
- **Suppression of visual cortex has been shown for maintaining spatial relations compared to spatial locations** (Ikkai et al. 2014)

Question of Interest

Can changes in activation related to increasing WM load elucidate the nature of these dissociable types of information in spatial WM and their underlying neural substrates?

Method

- **N = 23 participants**
  - **8 males, *M* age = 22, *SD* = 4.1**
- **Participants completed 288 trials in scanner**
  - **144 Location trials (50% low/high load)**
  - **144 Relation trials (50% low/high load)**
- **Retinotopic mapping procedures were used to identify dorsal/ventral early visual regions**
- **Anatomical scans were used to create a segmented and inflated surface model**
  - **Functional data were projected onto the surface and analyzed via AFNI/SUMA**

WM Task: Location vs. Relation

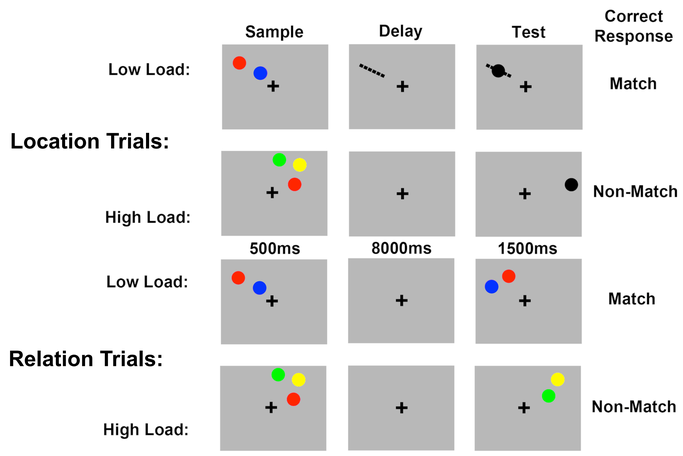

Figure 1. LOCATION TRIALS: Participants were required to maintain 1 or 3 spatial locations in WM (i.e., *Low load*: maintain the location of a line between the two circles (line shown here only for illustration); *High load*: maintain the locations of all 3 circles). RELATION TRIALS: Participants were required to maintain 1 or 3 spatial relations in WM (i.e., *Low load*: maintain relative vertical relationship between 2 circles; *High load*: maintain 3 relative vertical relationships between 3 circles).

Behavioral Results

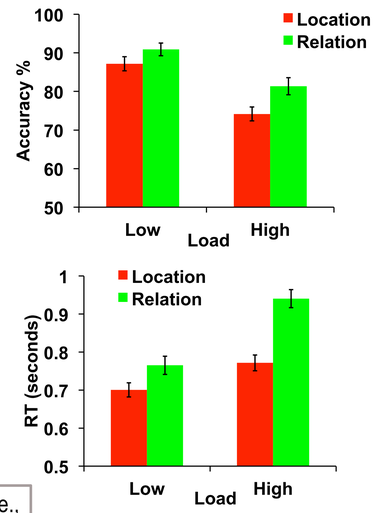

Figure 2. *Accuracy data:* significant main effects of load and trial type, *p*s<0.001. Interaction was n.s. *RT data:* significant main effects and interaction, *p*s<0.001

Visual Cortex ROI Results

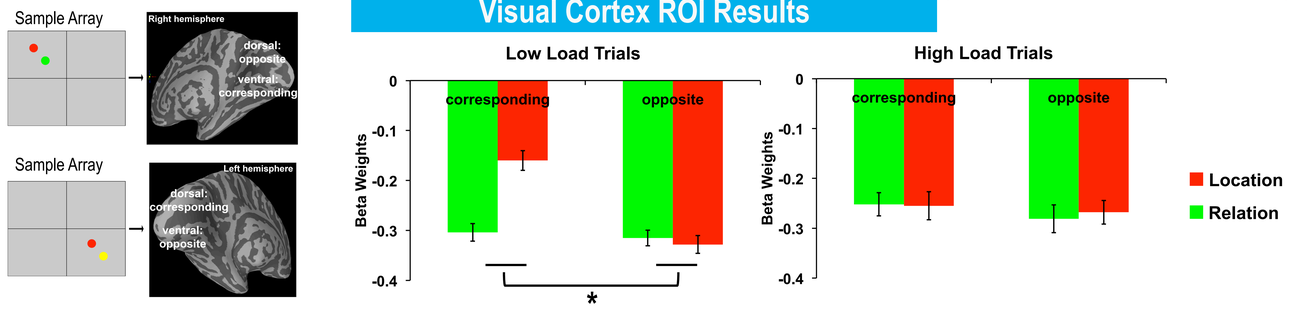

Figure 3. Early visual cortex (V1-V3) showed less delay period retinotopic BOLD activity for Relation trials compared to Location trials for Low load. However, for High load there was no difference in visual cortex BOLD activity for the two trial types. *p<0.001.

Whole Brain Results

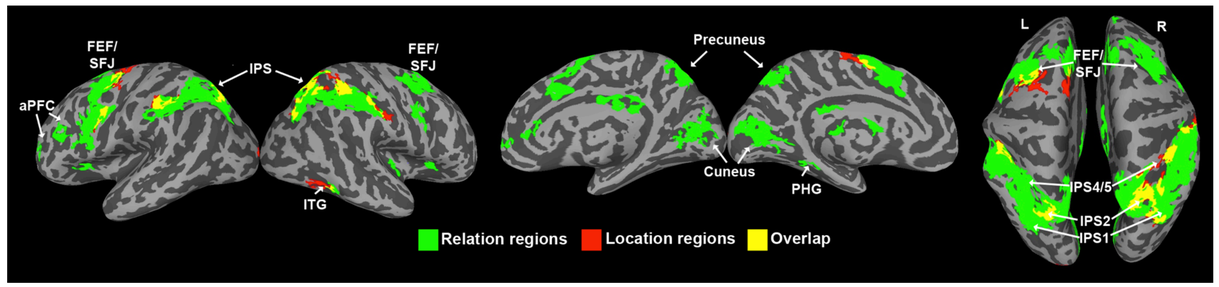

Figure 4. Red shows regions that were more active for High compared to Low load for LOCATION trials. Green shows regions that were more active for High compared to Low load for RELATION trials. Yellow shows regions that were modulated by load for both trial types.

Acronyms: Frontal Eye Fields (FEF), Superior Frontal Junction (SFJ), Intraparietal Sulcus (IPS), Parahippocampal Gyrus (PHG), anterior Prefrontal Cortex (aPFC), Inferior Temporal Gyrus (ITG)

Results Summary

- **WM load differentially influenced early visual cortex activity for maintaining Relations vs. Locations:**
  - **Low load: there was less retinotopic BOLD activity for maintaining 1 spatial Relation vs. 1 Location in WM**
  - **High load: there was no difference in early visual cortex activation across trial types**
- **There was a dissociation within the inferior temporal cortex with load modulating activation posteriorly for Locations and anteriorly for Relations.**
- **There was also a posterior-anterior dissociation within and near FEF, with WM load modulating activation posteriorly for Locations, and anteriorly along the SFS for Relations**
- **Within and near IPS, distinct subregions were sensitive to load for each trial type or both:**
  - **IPS1 was primarily modulated by Relation load**
  - **IPS2 bilaterally was modulated by both types of load**
  - **IPS4/5 was more dependent on Location load on the right and Relation load on the left**
  - **Areas in more medial and inferior-lateral parietal cortex were modulated only by Relation load**

Conclusions

- **WM load differentially activated distinct subregions of the IPS, FEF, and ITG when spatial Locations vs. Relations were maintained in WM**
- **These data provide further support for the idea that the neural system underlying spatial WM contains distinct representations for individual object locations and spatial relationships between objects**
- **The neuroanatomical organization of these types of information suggest that other anterior-posterior and medial-lateral dissociations that have been previously observed** (Badre 2008; Kravitz et al. 2011) **may also reflect dissociations in the type of information required for different tasks**

References

Ackerman, C. M., & Courtney, S. M. (2012). Spatial relations and spatial locations are dissociated within prefrontal and parietal cortex. *Journal of Neurophysiology, 108*(9), 2419-2429.

Badre, D. (2008). Cognitive control, hierarchy, and the rostro-caudal organization of the frontal lobes. *Trends in Cognitive Sciences, 12*(5), 193-200.

Ikkai, A., Blacker, K.J., Lakshmanan, B.M., Ewen, J.B., & Courtney, S. M. (2014). Maintenance of relational information in working leads to suppression of the sensory cortex. *Journal of Neurophysiology, 112*(8), 1903-1915.

Kravitz, D. J., Saleem, K. S., Baker, C. I., & Mishkin, M. (2011). A new neural framework for visuospatial processing. *Nat Rev Neurosci, 12*(4), 217-230.

Olson, I. R., Moore, K. S., Stark, M., & Chatterjee, A. (2006). Visual working memory is impaired when the medial temporal lobe is damaged. *Journal of Cognitive Neuroscience, 18*(7), 1087-1097.

Silver, M. A., & Kastner, S. (2009). Topographic maps in human frontal and parietal cortex. *Trends in Cognitive Sciences, 13*(11), 488-495.

Wang, L., Mruczek, R. E., Arcaro, M. J., & Kastner, S. (2014). Probabilistic Maps of Visual Topography in Human Cortex. *Cerebral Cortex*.

Acknowledgements & Reprints

We wish to thank Serban Negoita & Cody Elias for help with data collection and analysis.

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