Decreased Retinotopic Representation during Maintenance of Abstract Spatial Relations in Working Memory

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Introduction

• The neural mechanisms of visuospatial working memory (WM) are well-known (e.g., Courtney et al., 1996, 1998).

• However, very little is known about how abstract, non-sensory information is maintained in WM:
  • E.g., rules, relationships, strategies

• Previous work has begun to suggest that there may be distinct neural mechanisms for abstract vs. sensory WM (Ackerman & Courtney, 2012; Montojo & Courtney, 2008).

• Evidence from EEG suggests that when abstract spatial relations are maintained in WM, sensory cortex is suppressed, as compared to when sensory information is maintained (Ikkai, Blacker et al., 2014).

Questions of Interest

• Does maintenance of abstract spatial relations in WM result in less retinotopic activity in visual cortex compared to maintaining concrete spatial locations in WM?

• Are there distinct neural correlates underlying WM for abstract, non-sensory information vs. WM for item-specific sensory information?

Method

• N = 25 participants
  • 6 males, M age = 21, SD = 2.6
  • 1 hour training session prior to fMRI
  • Participants completed 160 trials in scanner (50% each trial type)
  • Retinotopic mapping procedures were used to identify dorsal and ventral portions of V1, V2, V3
  • High resolution anatomical scans were used to create a segmented and inflated surface model
  • Functional data were projected onto the surface and analyzed via AFNI/SUMA

Whole Brain Results

• Maintaining abstract spatial relations in WM resulted in decreased retinotopic BOLD activity in areas V1-V3, as compared to maintaining concrete spatial locations in WM.

• This difference was most evident in the regions of visual cortex responsible for processing the area of visual space where the sample array was initially presented.

• Whole-brain results showed a dissociation between WM for abstract vs. concrete spatial information:
  • Item trials activated typical spatial WM regions in posterior parietal and superior frontal cortices (e.g., Courtney et al., 1998, Hagler & Sereno, 2006).
  • Relation trials activated relational processing areas in the left medial temporal lobe (MTL) (e.g.,Olson et al., 2006).

Conclusions

• WM for abstract vs. concrete information appears to rely on distinct neural mechanisms.

• Maintenance of abstract spatial information is associated with less retinotopic visual cortex activity than maintenance of concrete spatial information.

• The MTL appears to be active during short-term maintenance of non-sensory relational information, such as spatial relationships.

References


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Figure 1. Item trials: an imaginary line between the sample circles was encoded and held in WM. At test, participants decided if the test circles "straddled" the imaginary line. Relation trials: the relative vertical positions of the sample circles were encoded and held in WM and compared to the test circles.

Figure 2. Accuracy and RT data. *p<0.01

Figure 3. Early visual cortex showed less delay period retinotopic BOLD activity when an abstract spatial relation was maintained in WM compared to when a spatial location was maintained, as evidenced by trial type x quadrant region interactions, *p<0.005

Figure 4. Double-dissociation showing distinct regions that were more active when a spatial location was maintained in WM (Item: cool colors) and distinct regions that were more active when a spatial relation was maintained in WM (Relation: warm colors).

Acronyms:

Frontal Eye Fields (FEF)
Superior Frontal Junction (SFJ)
Intraparietal Sulcus (IPS)
Superior Inferior Parietal Lobule (SII/PL)
inferior Precentral Sulcus (inf-PCS)
Parahippocampal Gyrus (PHG)