Mechanisms of spatial versus non-spatial, modality-based attention

Daniel Baldauf & Robert Desimone

McGovern Institute for Brain Research, Massachusetts Institute of Technology,

Introduction: Previous research has highlighted the role of a dorsal attention network as sources for spatial attention signals (Bichot et al., 2005; Buschmann & Miller, 2009; Siegel et al., 2008; Gregoriou et al., 2009). When covertly attending to a location in space, the frontal eye fields (FEF) and posterior parietal cortex (PPC) send top-down spatial biasing signals to retinotopically organized visual areas, and facilitate the processing of incoming sensory information by a combination of firing rates and synchrony at gamma frequency. Experimental work has begun to also shed some light on a different control network providing sources for non-spatial attentional biases. It has been suggested recently that abstract, categorical task representations in the inferior part of frontal cortex route biasing signals to high-level visual representations of attended features and objects in extrastriate cortex (Gazzaley & Nobre, 2012; Baldauf & Desimone, 2014; Bichot et al., 2015). How do these two different systems work together in natural scenarios that require both spatial and non-spatial cues at the same time? Here we tried to tease apart the respective contributions of both networks within a combined cueing task, comparing top-down attentional networks for spatial and non-spatial attention.

Methods: We used temporally high-resolving MEG recordings together with decoding procedures in fMRI scans within the same subjects to optimize both spatial and temporal imaging resolution. To investigate the temporal dynamics and interactions among fMRI-defined areas, we co-registered the sites with our temporally high-resolving MEG recordings. A task with cues to attend to the visual or auditory modality on either the left or right side was used to study both spatial and non-spatial top-down signals (Fig.1A).

Results: Attention to spatial locations and sensory modality (auditory versus visual) caused enhanced evoked responses and BOLD signals in early sensory areas (Fig.1B).

Multiple voxel pattern analysis (MVPA) of FMRI data revealed spatial and non-spatial (modality-based) control networks in superior-frontal and inferior-frontal cortex, respectively (Fig. 2).

The fMRI-defined control networks and sensory areas were then co-registered with the temporally high-resolving MEG. During the delay period - following the attentional cue, but before any targets had been presented - we observed locally in the four sensory ROIs a systematic pattern of decreased alpha power (10-12Hz), accompanied by increased high-frequency power (40-90Hz) when attention was directed into the respective site (Fig. 3).

To test for functional interactions between the sensory areas and the control areas in frontal and parietal cortex, we analyzed inter-areal phase coherence across a wide frequency spectrum. When spatial attention was directed to a location mapped by a sensory area, coherence between this area and both FEF and PPC increased in a range from 50-90Hz, whereas coherence with IFJ did not (Fig. 4). Conversely, when modality attention was directed into a respective sensory area, coherence increased between the sensory site and IFJ in a similar range of the spectrum, but less so with FEF or PPC.

Conclusions: Our results suggest that different prefrontal structures are sources of top-down biasing signals for spatial and non-spatial attention, and these structures interact in a similar fashion with posterior sensory areas during sustained attention.

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