Similarity-based fusion of MEG and fMRI reveals spatio-temporal dynamics in human cortex during visual object recognition

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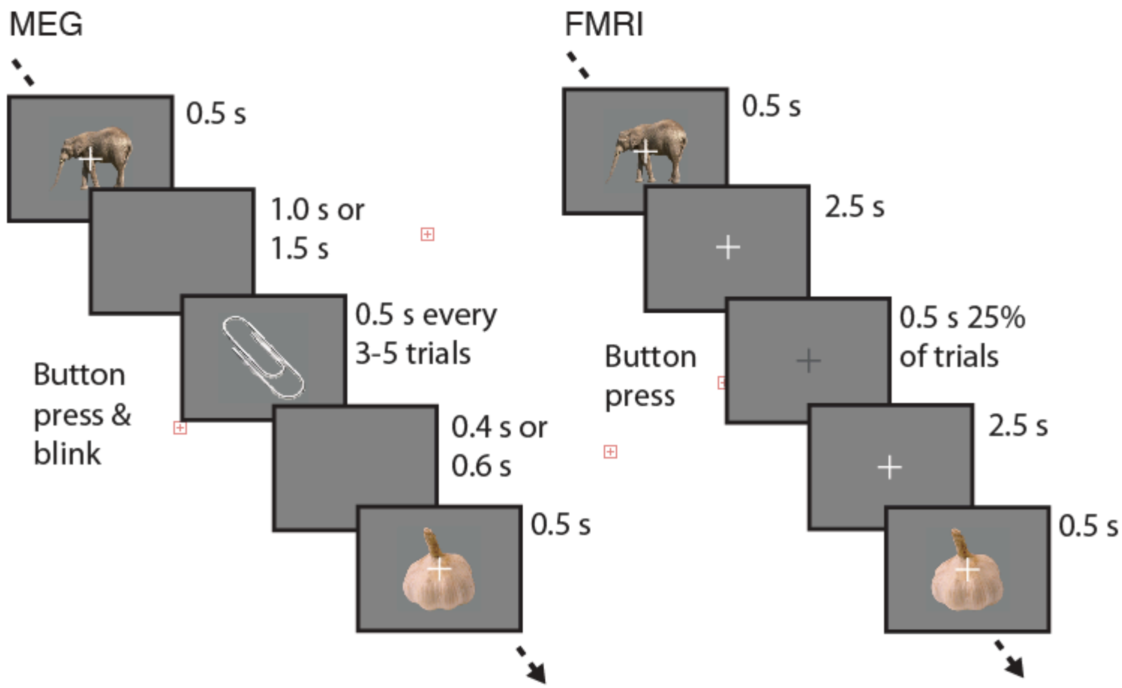
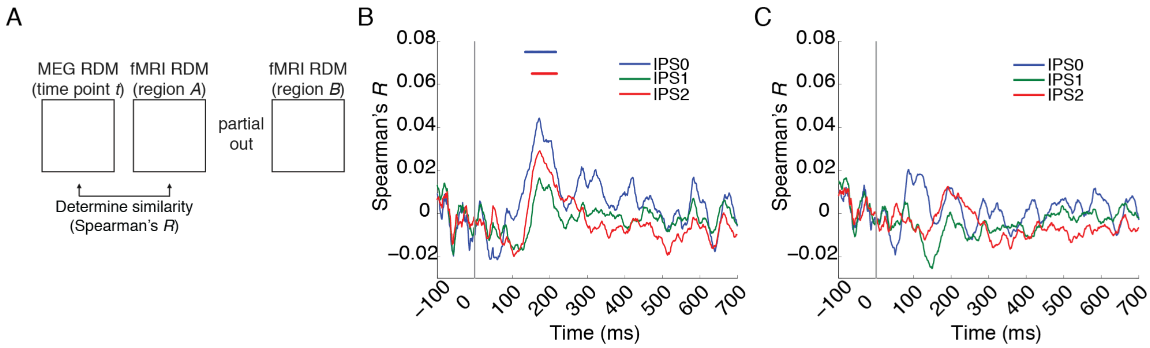
Supplementary Material

Supplementary Figure 1



Supplementary Figure 1: Experimental design in MEG and fMRI (images exemplary for experiment 1). Participants viewed images of a set of 92 images (Experiment 1; 2.9° visual angle, 0.5s presentation time) or 118 images (Experiment 2; 2.9° visual angle, 0.5s presentation time) overlaid with a light gray fixation cross in random order. We adapted presentation parameters to MEG and fMRI. **(a)** For MEG, the trial onset asynchrony (TOA) was 1 or 1.5s. Every 3-5 trials (average 4) a paper clip image was presented and participants were instructed to blink their eyes and press a button. **(b)** For fMRI, the TOA was 3s or 6s after a null trial. During null trials no image was presented, and the fixation cross changed hue to a darker gray, to which participants responded with a button press.

Supplementary Figure 2



Supplementary Figure 2: Partial correlation analysis of the relationship between activity in dorsal with activity in ventral regions and EVC. A) We compared MEG RDMs to dorsal-region fMRI RDMs after partialling out either **B)** EVC or **C)** all ventral regions. Results showed significant MEG-fMRI correspondence even after partialling out EVC, but not after partialling out ventral visual regions. This shows that representations in dorsal regions are discriminable from representations in EVC, but provides no leverage on the question of representational similarity for dorsal and ventral regions. N=15, significant time points indicated by colored lines above time courses, $p<0.05$ cluster definition threshold, $p<0.05$ cluster threshold.

Supplementary Results 1: Partial correlation analysis

We explored whether parietal cortex represents objects differently than early visual cortex, or high-level ventral visual cortex. For this we used a partial correlation analysis (Supplementary Figure 2A). That is, we determined for IPS0, 1 and 2 whether significant effects remained when the effect of EVC and high-level ventral visual regions was accounted for. We found significant MEG-fMRI correspondence after partialling out EVC in IPS0 and IPS2 (Supplementary Figure 2B), but not after partialling out ventral visual regions (Supplementary Figure 2C).

How can these results be interpreted with regard to the large-scale structure of object representations in human visual cortex? The finding of significant MEG-fMRI correspondence in IPS1 and 2 after partialling out EVC suggests that object representations in EVC and dorsal cortex at least partly differ. However, this does not establish that EVC and dorsal cortex do not also share common aspects of object representations. Together with the finding that MEG-fMRI correspondence peaked later for dorsal regions than for EVC, this suggests that dorsal cortex processes objects in a hierarchical fashion in space and time (Konen and Kastner, 2008; Kravitz et al., 2011).

The lack of significant MEG-fMRI correspondence in dorsal regions when the effect of ventral regions is accounted for needs to be interpreted with care. The negative result provides no positive proof that MEG-fMRI correspondence in dorsal and ventral regions depends on the same representations for two reasons. First, the lack of an effect is no proof for its absence as known in inferential statistics. Second, by its nature, representational similarity analysis can only capture relations in similarity, not the information encoded in the representation directly. Similarity in representational relations for two regions is thus still consistent with the possibility that the two regions represent different information. For example, there is evidence that dorsal and ventral cortex represent different types of object information, e.g. shape information (Kourtzi and Kanwisher, 2000; Reddy and Kanwisher, 2006) in ventral vs. spatial and depth information in dorsal cortex (Orban, 2011; Freud et al., 2015). In natural stimuli as used in experiment 2, these types of information are interdependent and two regions might appear similar when probed with representational similarity analysis, while in fact representing different information. Thus, other approaches are necessary to further investigate the relationship between dorsal and ventral representations. Future studies in lesion patients (Konen et al., 2011; Freud et al., 2015) under special experimental conditions, such as continuous flash suppression (Fang and He, 2005) and using artificial stimulus sets, with the MEG-fMRI fusion technique are necessary to further explore this unresolved issue.

Supplementary References

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