



Background:

The coding of relations is fundamental to human cognition. Most visual experience is composed of scenes, where the interactions among objects define the relations. The saliency of object interactions is readily described by prepositions or gerunds, e.g., a hand holding a pen, and appears to be immediately appreciated (Biederman et al., 1982; Green & Hummel 2006).

At what stage in the ventral visual pathway does sensitivity to such interactions arise? What is the time course of these scene-like interactions?

Overview of Three fMRI Experiments

Stimuli for All Exps:



Experiment 2: Control for Foveal Magnification

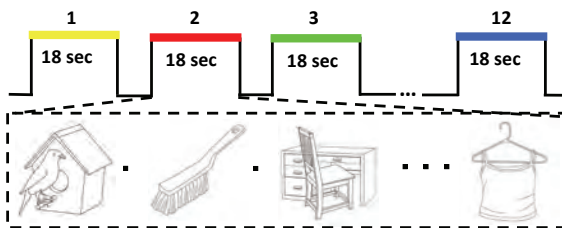


Experiment 3: Control for Relative Size



In Exp. 1, interacting stimuli were presented centrally and the side-by-side stimuli flanked central fixation. In Exp. 2, interacting objects were presented off-center, matching one of the positions of the side-by-side objects. In Exp. 3, the side-by-side objects were depicted in their correct relative sizes.

fMRI Block Design Experiments:



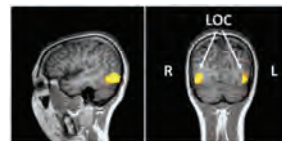
Exps. 1 & 2: Odd man out task

Subjects counted how many times (0, 1, or 2) a single object appeared within a block (shown above).

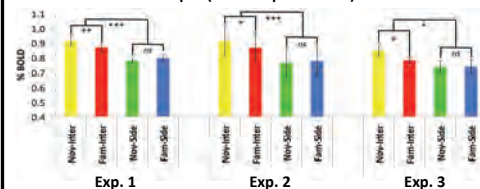
Exp. 3: One back task

Subjects detected if there was a repetition of a scene.

fMRI Results in LOC



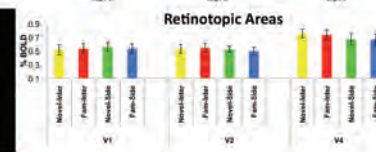
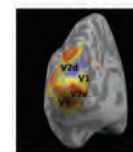
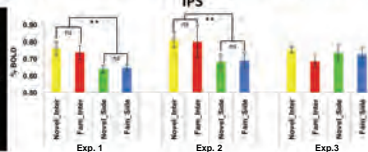
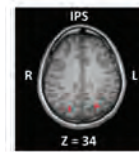
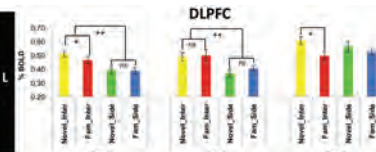
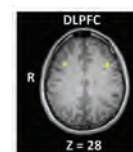
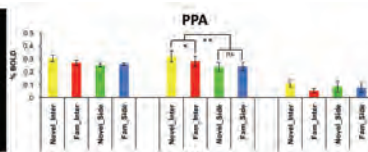
pFs (anterior part of LOC)



Main Result:

In all three experiments, LOC was the only region that **consistently** showed larger BOLD responses to interacting than side-by-side images and to novel over familiar interactions.

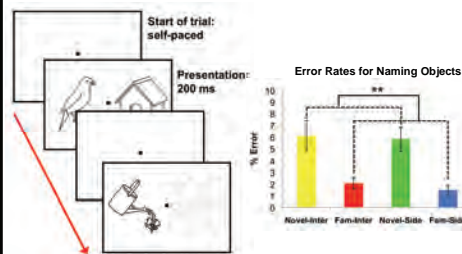
fMRI Results in PPA, IPS, DLPFC, and Early Visual Areas



PPA, which shows activation for places or spatial layout (Epstein & Kanwisher, 1998; Epstein et al. 2003), and IPS and DLPFC, both reflecting attentional demands or task related processes (e.g., Corbetta & Shulman, 2002; Heekeren et al., 2006) did not consistently reveal the pattern of BOLD effects seen in LOC.

The effects seen in LOC were not feed-forward from early visual cortex.

Interacting Objects Are Not More Difficult to Recognize

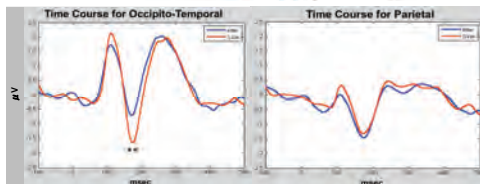


To assess whether visual complexity or difficulty of object identification could have contributed to the greater activity of the interacting than the side-by-side conditions, a naming experiment was done.

Subjects were equally accurate in identifying objects in the interacting and side-by-side conditions. Object naming was easier for the familiar than novel pairs.

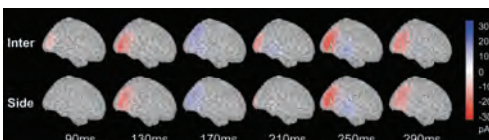
Biederman, I. et al. (1982). Scene perception: detecting and judging objects undergoing relational violations. *Cognit Psych*, 14, 143-177.
 Cant & Goodale M.A. (2007). Attention to form or surface properties modulates different regions of human occipitotemporal cortex. *Cereb. Cortex* 17, 713-731.
 Corbetta, M. & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nat. Rev. Neurosci.* 3, 203-215.
 Epstein R. & Kanwisher, N. (1998). A cortical representation of the local visual environment. *Nature* 392, 598-601.
 Epstein, R. et al. (2003). Viewpoint-specific scene representations in human parahippocampal cortex. *Neuron* 37, 865-876.
 Green, C. & Hummel, J.E. (2006). Familiar interacting object pairs are perceptually grouped. *J Exp Psychol*, 32, 1107-1115.
 Heekeren, H.R. et al. (2006). Involvement of human left dorsolateral prefrontal cortex in perceptual decision making is independent of response modality. *PNAS* 103, 10023-10028.

EEG Experiment



The occipito-temporal electrodes showed a significant divergence of the Inter vs. Side conditions in the N170 component. There was no consistent effect of interaction or novelty in any other areas.

Source estimation showed similar results.



Conclusions:

- In all three fMRI Exps., we witnessed the identical signatures of scene-like relations in LOC: greater activation to interacting than side-by-side depictions and an additional boost from the novelty of the interaction.
- PPA, IPS and DLPFC showed inconsistent responses across the Exps., rendering it implausible that the pattern shown in LOC is a direct consequence of these regions.
- Results in LOC can not be explained by visual complexity, foveal magnification, relative size, task difficulty or activity from early visual areas.
- EEG results showed that the divergence of the Inter vs. Side conditions was evident only in the occipito-temporal (i.e., LO) region. No other region manifested an effect of the interactions much less as early as LOC.
- Given that LOC is the first area where object shape is distinguished from texture (Cant & Goodale, 2007), the fMRI and EEG results suggest that scene-like relations are specified at the same cortical region as object shape.

Bottom Line (consistent with our subjective impressions): **An object's shape is perceived simultaneously with its interactions with other objects.**