Cortical areas encoding visual segmentation cues from relative motion and relative disparity

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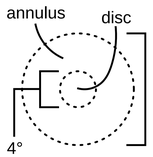
Background

Visual segmentation cues, such as differences in binocular disparity and motion, make important contributions to figure-ground segmentation.
These cues strongly co-vary at object boundaries and visual areas that encode both may support robust representations of objects and surfaces.

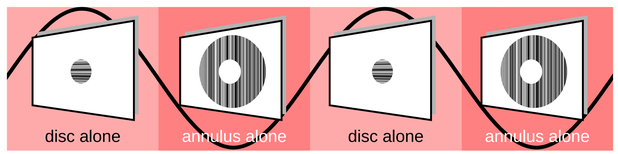
Here we use fMRI to investigate responses in human visual cortex to a figure defined using either motion or relative disparity, and compare them to responses generated by a contrast-defined version of the same figure.

Stimulus

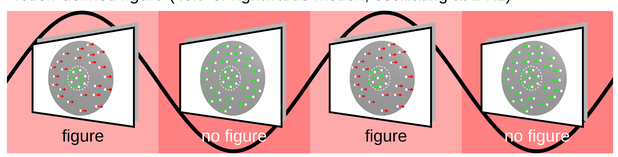


A disc-shaped figure region was defined in three ways: *contrast*, *motion* or *disparity*.
Stimulus dimensions were kept constant for all conditions.
Each condition oscillated between two states at 2 Hz.
For contrast, 12-sec blocks with the disc alone alternated with blocks in which only the annulus was shown.
For motion and disparity, the disc and annulus were either in anti-phase (so that a figure was seen) or in phase (no figure) in separate 12-sec blocks.

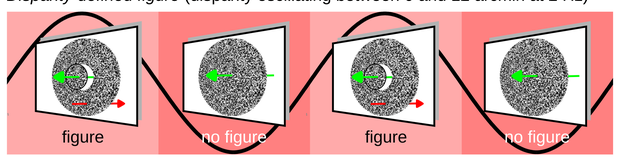
Contrast-defined figure (orientation vertical or horizontal, oscillating at 2 Hz)



Motion-defined figure (left- or rightwards motion, oscillating at 2 Hz)



Disparity-defined figure (disparity oscillating between 0 and 12 arcmin at 2 Hz)



A block (12s) B block (12s) A block (12s) B block (12s)

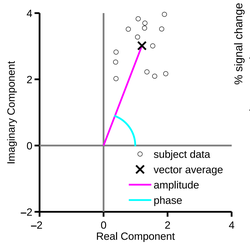
References

Amano K, Wandell BA, Dumoulin SO (2009) Visual Field Maps, Population Receptive Field Sizes, and Visual Field Coverage in the Human MT+ Complex. Journal of Neurophysiology 102:2704-2718.
Reppas JB, Niyogi S, Dale AM, Sereno MI, Tootell RBH (1997) Representation of motion boundaries in retinotopic human visual cortical areas. Nature 388:175-179.
Wang L, Mruczek RE, Arcaro MJ, Kastner S (2015) Probabilistic Maps of Visual Topography in Human Cortex. *Cerebral Cortex 25*:3911-3931.

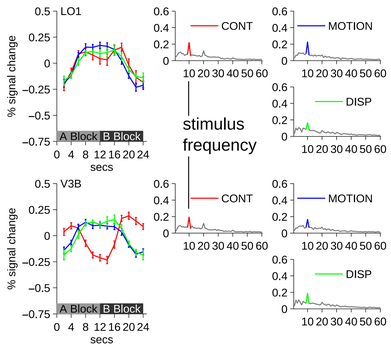
fMRI Data analysis

fMRI parameters
Ten 24-sec cycles per scan
4 scans per condition
2-sec TRs, 2 mm iso voxels

Time-courses for each condition were averaged across runs and voxels, within 18 retinotopic regions-of-interest defined using a probabilistic atlas (Wang et al., 2014)

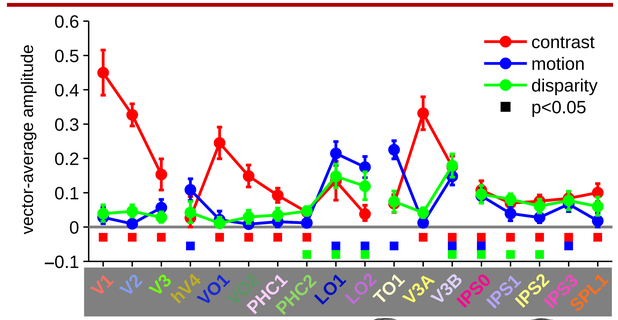


Mean response during one stimulus cycle and mean spectra for two example ROIs:



Responses were computed for each ROI based on a vector-based approach, which takes into account both amplitude and phase at the stimulus frequency.

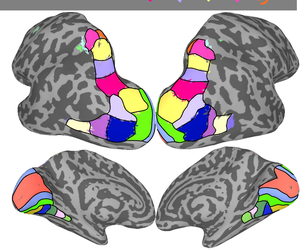
ROI results



The contrast condition evoked stronger responses in multiple ROIs, especially in early visual cortex.

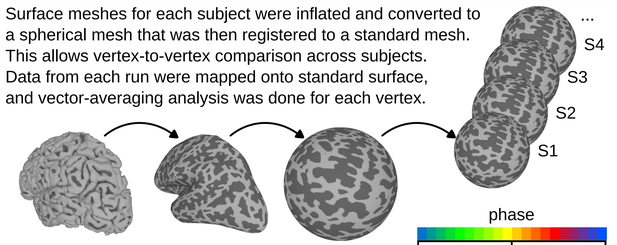
TO1 (corresponding to MT; Amano et al., 2009) and hV4 had strong responses to motion, but not the other two conditions.

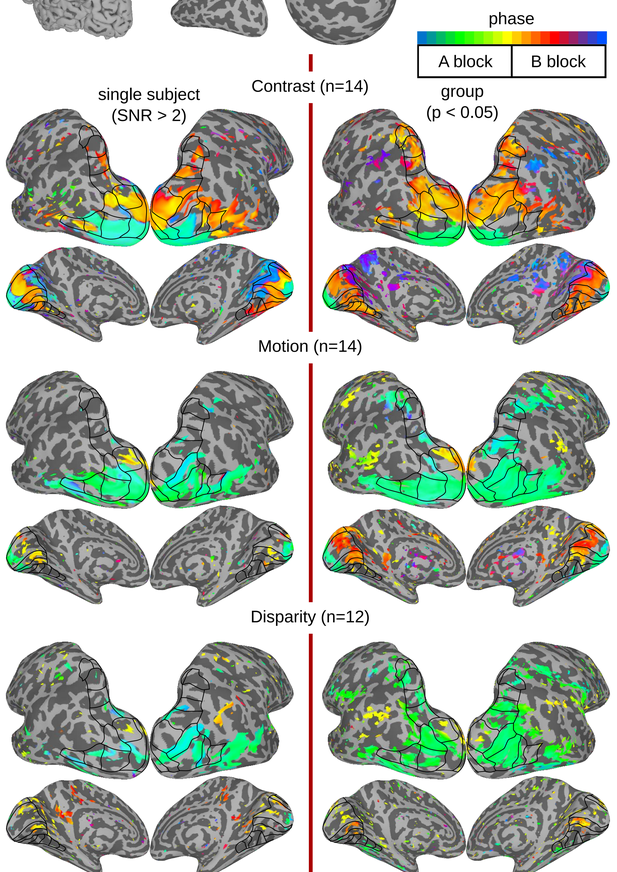
V3B and IPS0 both had significant responses in all conditions.



Whole-brain analysis

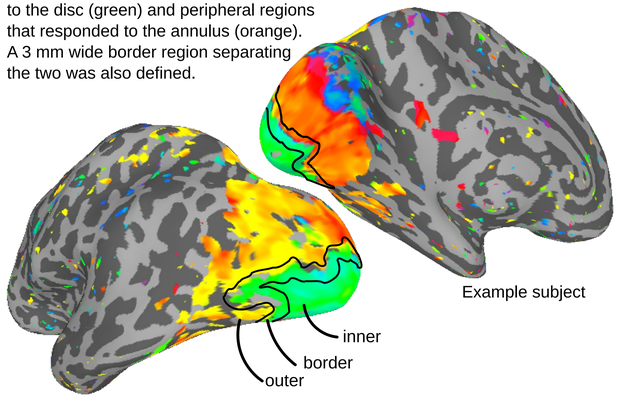
Surface meshes for each subject were inflated and converted to a spherical mesh that was then registered to a standard mesh.
This allows vertex-to-vertex comparison across subjects.
Data from each run were mapped onto standard surface, and vector-averaging analysis was done for each vertex.

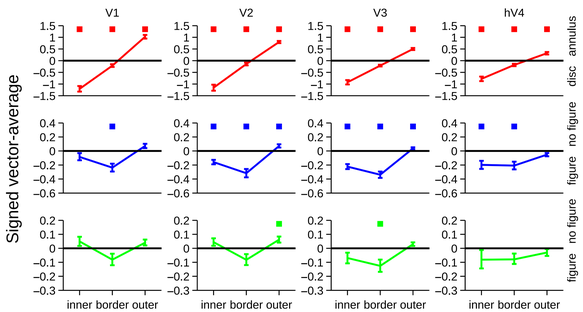




Sub-ROI analysis

Phase differences in the response across voxels within an ROI may lead us to underestimate the true response, when averaging across voxels.
To address this concern, sub-ROIs were defined for each individual subject based on the contrast data, such that visual areas V1-hV4 were split into foveal regions that responded to the disc (green) and peripheral regions that responded to the annulus (orange).
A 3 mm wide border region separating the two was also defined.





Significant responses to the motion-defined figure in all early visual areas (replicating previous findings by Reppas et al., 1997).

Significant responses to the figure defined by relative disparity were seen in V2 and V3, but not in hV4.

Conclusion

The joint encoding of figure-ground segmentation cues based on motion and disparity may involve a network of areas in human visual cortex, including areas as early as V2 and V3, as well as later areas, primarily in the dorsal visual processing stream.