Hierarchical Effects of Contrast and Motion Coherence in Early Visual Cortex

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Summary

Human discrimination of contrast tracks cortical responses in V1 and other early visual areas[1].

Here we used contrast discrimination based on V1 as a "ground truth" to jointly fit the discrimination of motion coherence.

Cortical responses in MT fit to motion coherence discrimination.

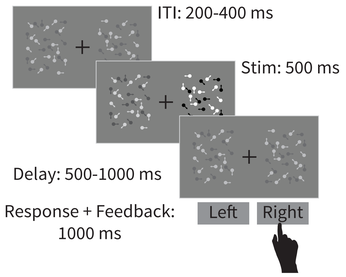
Early visual areas are sensitive to contrast and track behavior.

What areas do this for motion coherence?

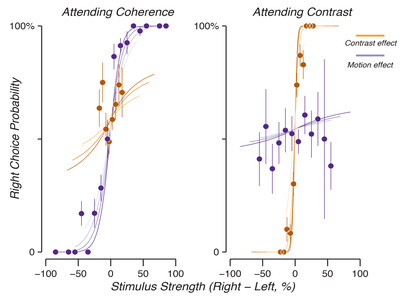
Task

Behavior was collected from subjects performing a 2-alternative forced choice discrimination task. On separate blocks subjects attended the stimulus contrast or motion coherence. The behavior was used to constrain a model of the underlying neural responses.

The dot stimulus stayed constant in the background at 25% constrast 0% coherence until each trial began.

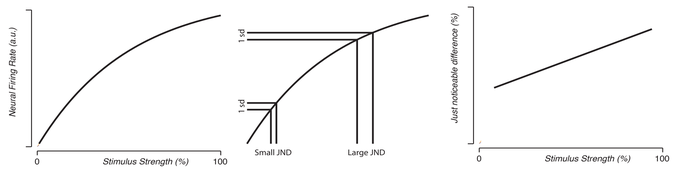


Example subject behavior and model fit

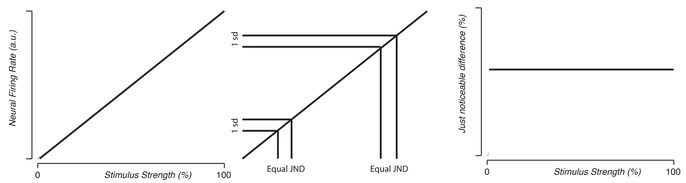


Discrimination performance

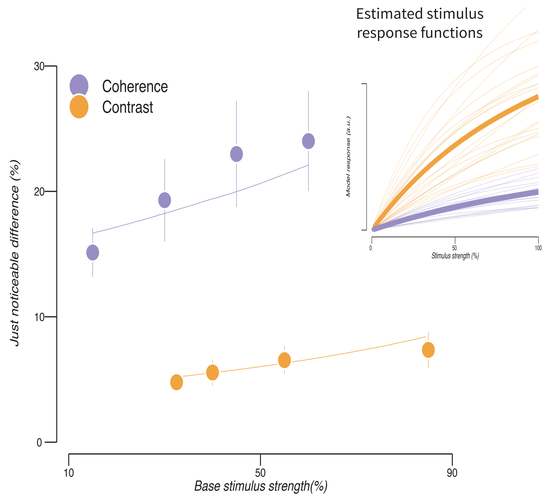
Subjects' "just noticeable difference" (JND) increased with base stimulus strength, as expected[1] if a non-linear neural response is used to perform signal detection.



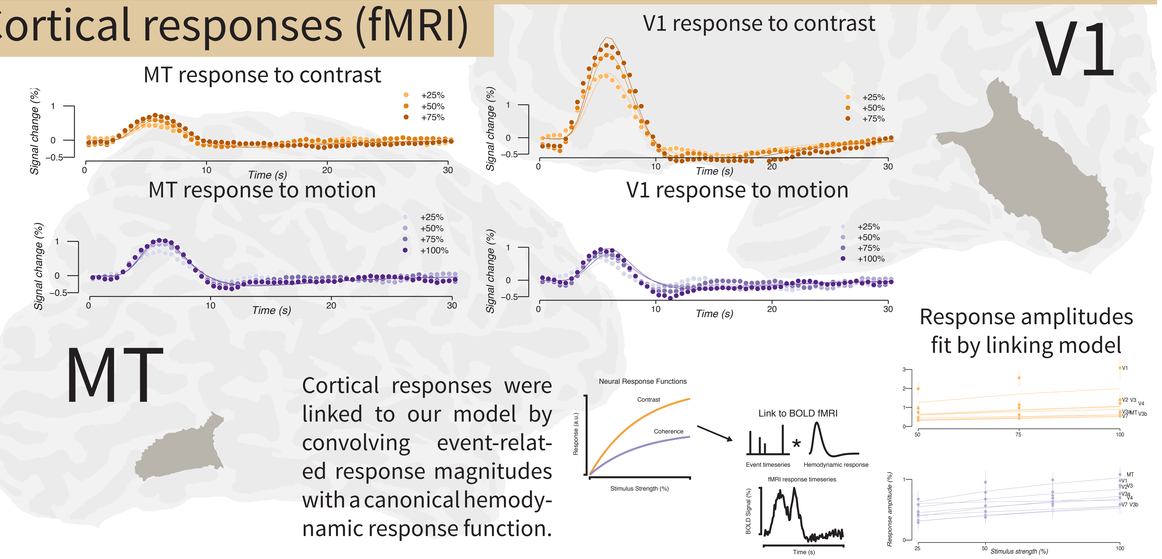
But previous work has suggested that the neural response to motion coherence is *linear*[2,3], which would result in a constant JND.



Just noticeable differences for contrast and motion coherence discrimination



Cortical responses (fMRI)



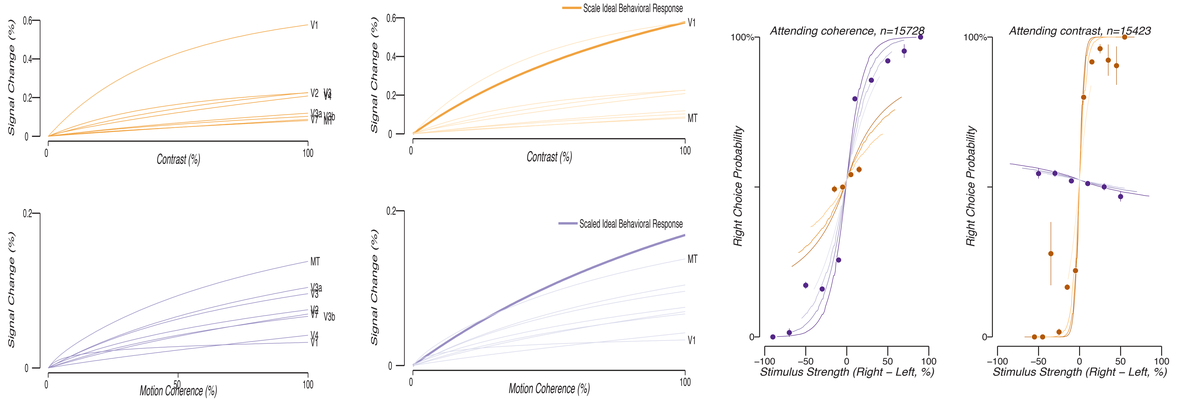
Cortical responses were linked to our model by convolving event-related response magnitudes with a canonical hemodynamic response function.

Response amplitudes fit by linking model

All cortical response functions $R_{neural}(s) = -\alpha e^{-\kappa s}$

Response noise estimated to fit behavior: sigma = 0.031%[5]

Behavioral fit using scaled cortical response functions



Conclusion

As expected, contrast discrimination performance fits the cortical response of neural populations in area V1. Using contrast to estimate noise we found that motion coherence discrimination fits to area MT. Contrary to expectations we found the cortical response in MT to be non-linear.

All figures present permutation test mean +- 95% CI across subjects (11 fMRI, 21 behavioral)

1. Boynton, G. M., Demb, J. B., Glover, G. H., & Heeger, D. J. (1999). Neuronal basis of contrast discrimination. Vision research, 39(2), 257-269.
2. Rees, G., Friston, K., & Koch, C. (2000). A direct quantitative relationship between the functional properties of human and macaque V5. Nature neuroscience, 3(7), 716-723.
3. Simoncelli, E. P., & Heeger, D. J. (1998). A model of neuronal responses in visual area MT. Vision research, 38(5), 743-761.
5. Reported values for neural noise of .064 and .016% for distributed and focal attention. Pestilli, F., Carrasco, M., Heeger, D. J., & Gardner, J. L. (2011). Attentional enhancement via selection and pooling of early sensory responses in human visual cortex. Neuron, 72(5), 832-846.

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