Joint fitting the neural basis of contrast and motion coherence in human visual cortex

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Summary

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

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

Cortical responses in MT and V3a fit to motion coherence discrimination, suggesting a neural basis.

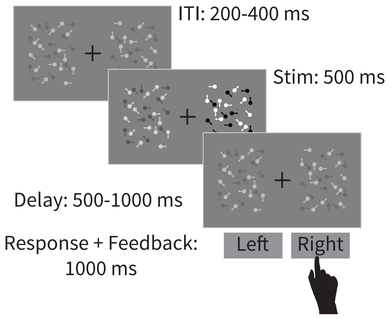
Early visual areas are sensitive to contrast and track behavior.

What areas do this for motion coherence?

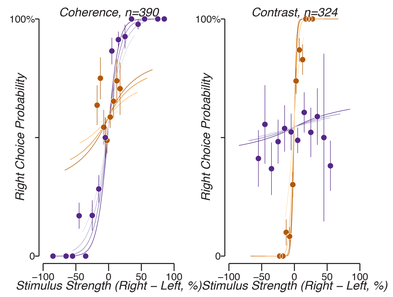
Task

Behavior was collected from 21 subjects performing a 2-alternative forced choice discrimination task (mean 2480 trials). On separate blocks subjects attended contrast or motion. The behavior was used to constrain a model of the underlying neural responses.

The dot stimulus had 21 dots/deg, 3 deg/s, and stayed constant in the background at 25% constrast 0% coherence until each trial began.

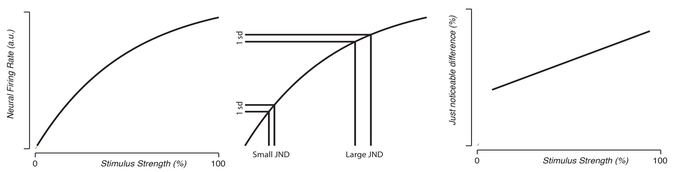


Example subject behavior and model fit

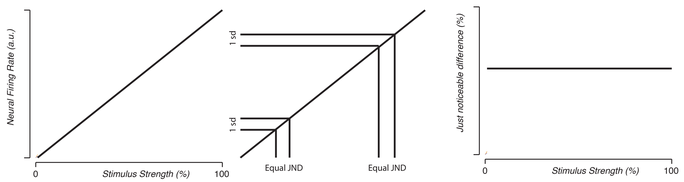


Discrimination performance

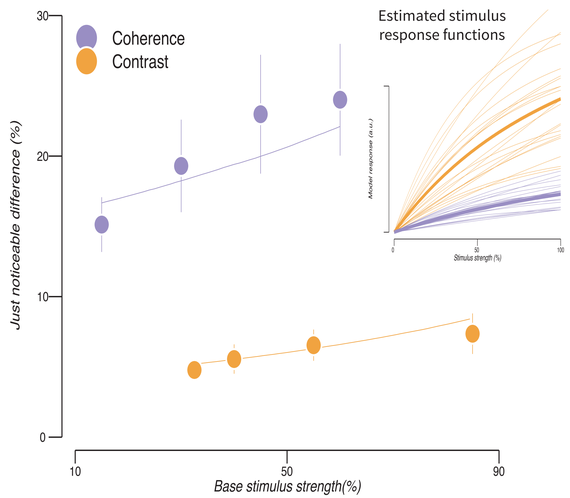
We found that subjects' "just noticeable difference" (JND) increased with base stimulus strength, as expected[1] if a non-linear neural response is used to perform signal detection.



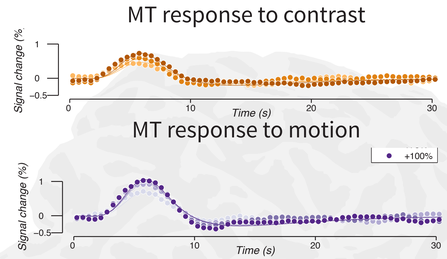
But previous work has suggested that the neural response to motion coherence should be *linear*[2,3], which would result in a flat JND line.



Just noticeable differences for contrast and motion coherence discrimination



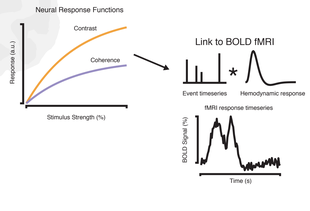
Cortical responses (fMRI)



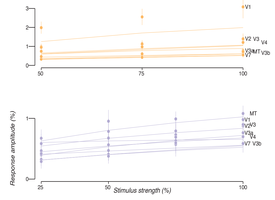
V1

MT

Cortical responses were modeled as changes in neural firing relative to the adapted state convolved with a per-subject hemodynamic response function.

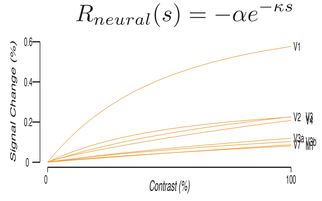


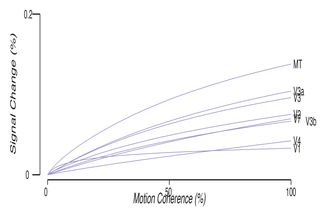
Response amplitudes fit by linking model



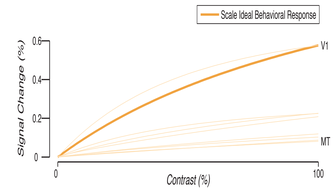
All cortical response functions

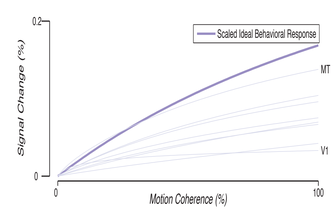
$$R_{neural}(s) = -\alpha e^{-\kappa s}$$



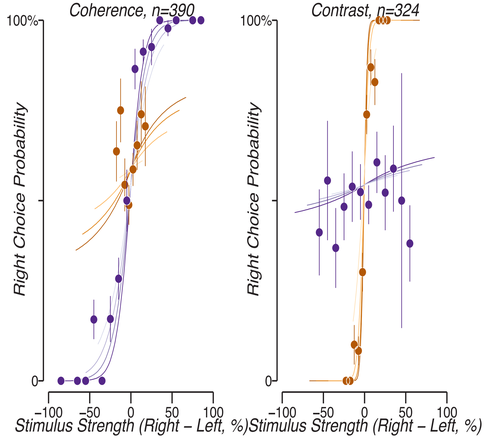


Behavioral functions scaled to fit contrast to V1; sigma = 0.031%[5]





Behavioral fit using scaled cortical response functions



Conclusion

Jointly fitting motion coherence and contrast discrimination to the neural responses of MT/V3a and V1 respectively is sufficient to explain behavioral performance on a 2-AFC discrimination task. Contrary to expectation this requires a non-linear representation of motion coherence.

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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