Hierarchical Effects of Contrast and Motion Coherence in Early Visual Cortex

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Summary

Using contrast discrimination based on V1 as a "ground truth" we jointly fit the discrimination of motion coherence. We found that cortical responses in MT, combined with additive neural noise,v best explain performance on a motion coherence discrimination task.

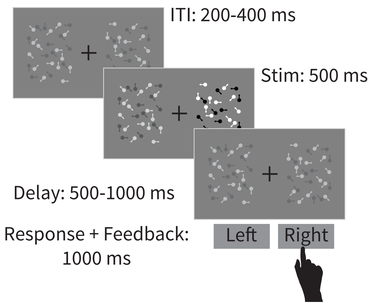
Early visual areas are sensitive to contrast and track behavior[1].

What areas do this for motion coherence?

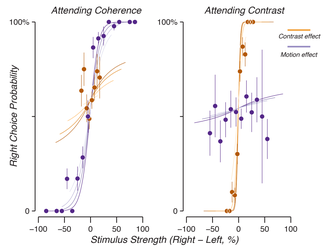
Task

Subjects performed a 2-alternative forced choice discrimination task (mean 1495 trials).

On separate blocks subjects attended contrast or motion coherence. Discrimination performance was used to constrain a model of the underlying neural responses.

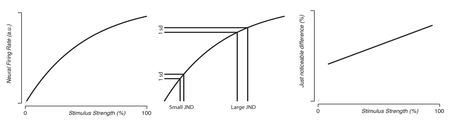


Example subject behavior and behavioral model fit

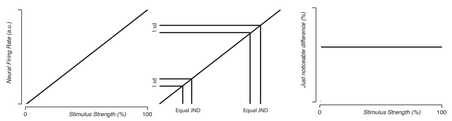


Discrimination performance

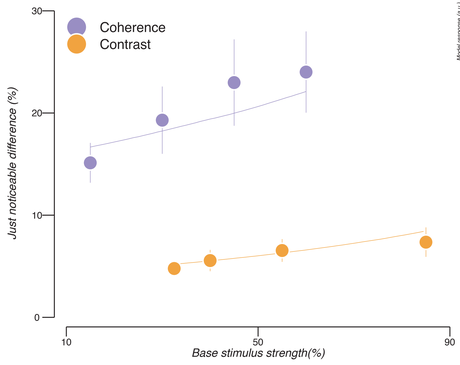
Under additive neural noise an increasing "just noticeable difference" (JND) with base stimulus strength indicates a non-linear neural response[2].



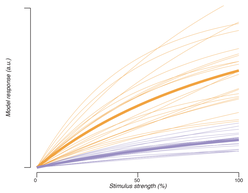
The JND would be flat if the neural response to motion coherence were linear[3,4].



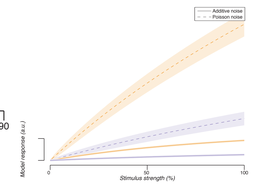
JND for contrast and motion coherence discrimination



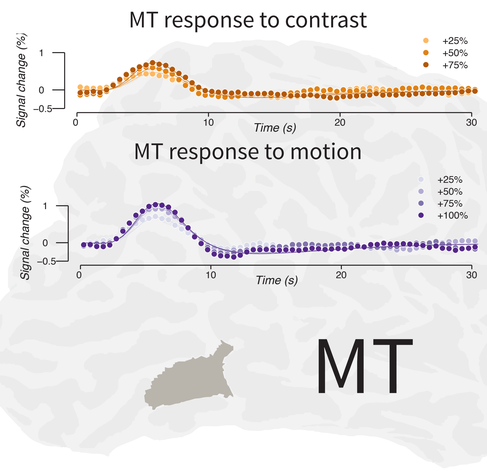
Behavior constrained stimulus response functions for additive noise



Average stimulus response functions for additive and poisson noise

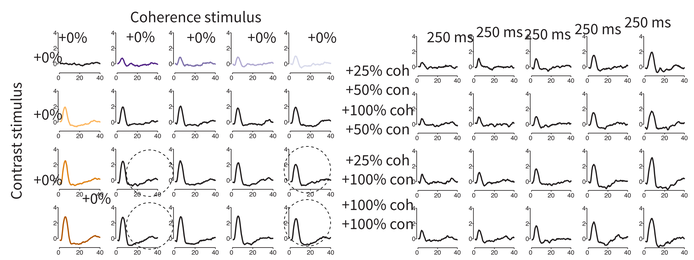


Cortical responses (fMRI)



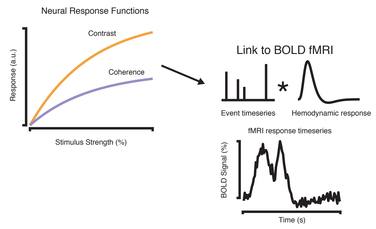
Example responses and fits shown for V1 and MT in a small slice of the data, only the 2500 ms constant contrast and motion coherence conditions. The linking model was constrained using all of the data.

Average responses for V1

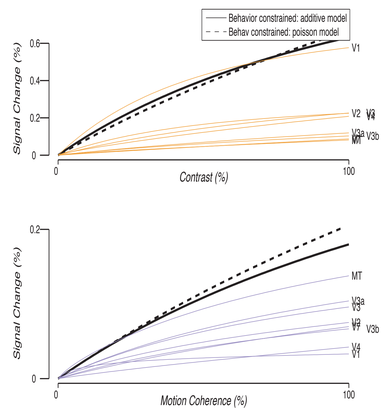


Linking model

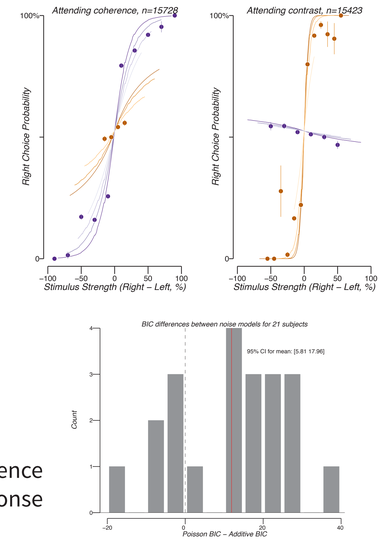
Cortical responses were used to constrain stimulus response functions by convolving event-related responses with a canonical hemodynamic response. The amount of neural noise[5] was fit: under additive noise 0.035% signal change, poisson: 0.005%



fMRI and behavioral constrained stimulus response functions[5]



Behavioral fit using cortical response functions and additive noise



Using contrast discrimination fit to V1 to estimate noise we found that motion coherence discrimination fits well to area MT. Contrary to expectation we found the cortical response in MT to be slightly non-linear.

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. We used a simplified form of the Naka-Rushton equation: $Response(s) = -\alpha e^{-\kappa s}$
3. 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.
4. Simoncelli, E. P., & Heeger, D. J. (1998). A model of neuronal responses in visual area MT. Vision research, 38(5), 743-761.
5. Previous reported values for neural noise in a similar model of contrast discrimination were .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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