Hierarchical effects of contrast and motion coherence in early visual cortex

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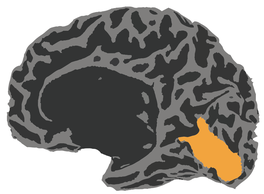
Summary

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

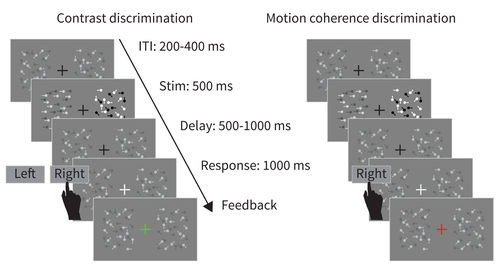


In this experiment we test the idea that to discriminate changes in visual contrast and motion coherence the brain might use the same strategy, but rely on different brain regions.

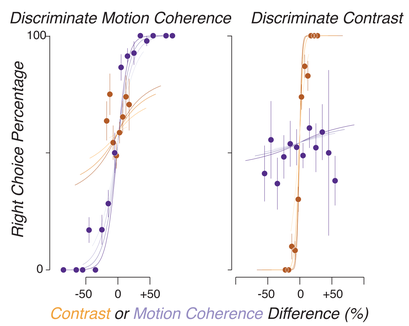
What areas do this for motion coherence?

Discrimination Task

Participants performed a 2-alternative forced choice discrimination task on contrast and motion coherence.

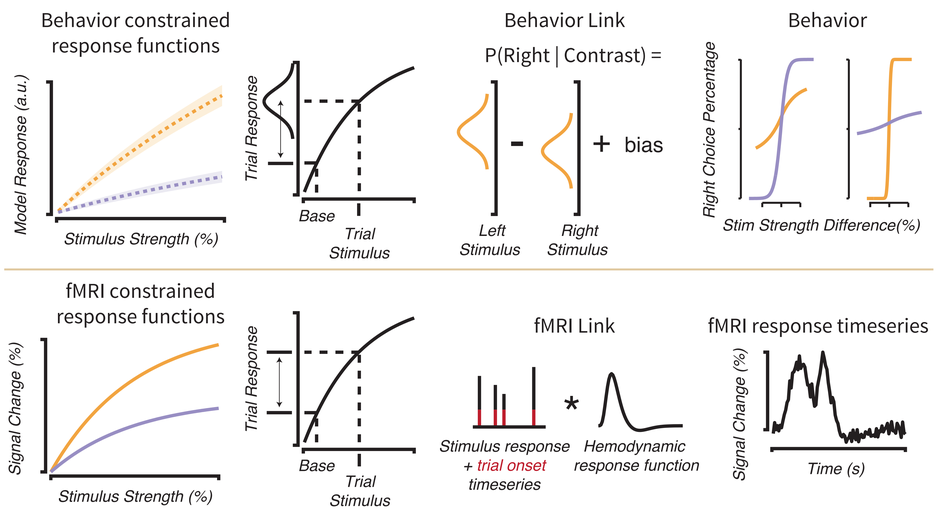


Example subject behavior

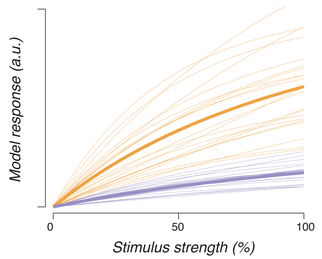


Linking model

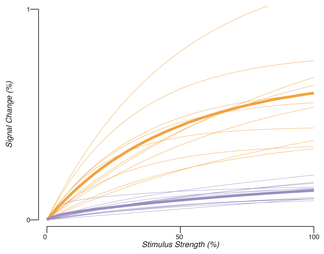
We generated stimulus response functions[1] constrained on the behavioral data and a separate set constrained on the fMRI data. The link to behavior is done via signal detection. The link to fMRI is a GLM.



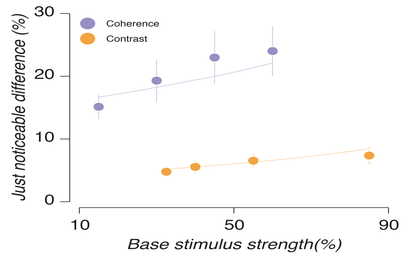
Contrast and motion coherence response functions constrained by behavior (n=21)



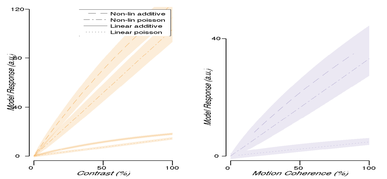
V1 and MT response functions constrained by fMRI (n=11)



Increasing just noticeable differences in the behavior suggest that the underlying responses are non-linear with additive noise or that the neural noise increases with stimulus strength (e.g. poisson).

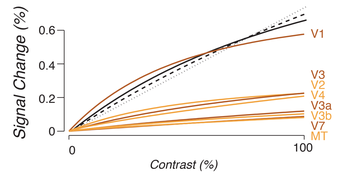


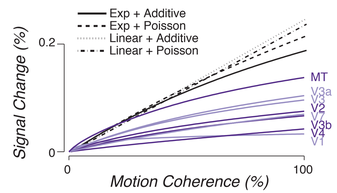
Optimal response functions



We fit a neural noise[5] parameter to scale response functions into the same space. Based on previous work[1] we fit this parameter using the functions constrained on V1 and constrast discrimination.

The linking model suggests that the responses in V1 and MT may be sufficient to explain contrast and motion coherence discrimination within the same computational framework.



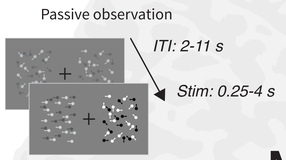


	Non-Lin + Additive	Non-Lin + Poisson	Linear + Additive	Linear + Poisson
Neural Noise Estimate (%)	0.0362	0.0056	0.0510	0.0022
Contrast ΔBIC	0	21.87	42.86	42.86
Motion ΔBIC	0	16.42	33.86	28.94

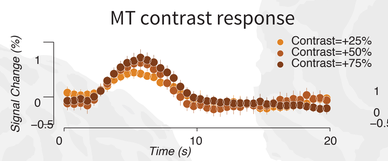
Std of preprocessed fMRI: 4.31% signal change (95% CI [4.01, 4.61])

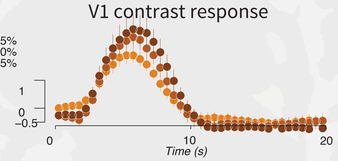
Cortical responses (fMRI)

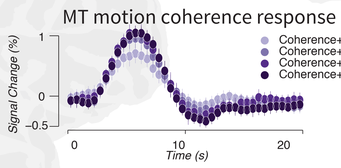
Cortical responses were recorded while subjects performed the discrimination task and during passive observation while fixating.

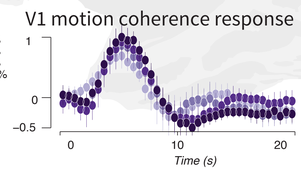


MT

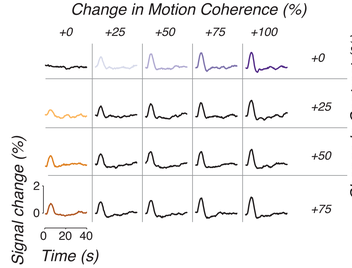




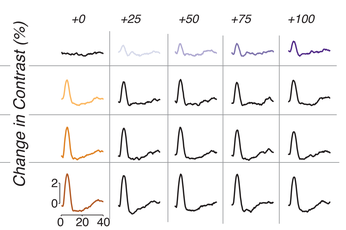




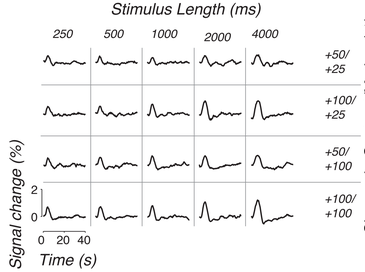
MT Contrast/Coherence Averages



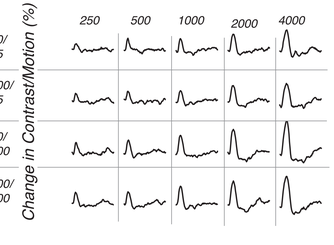
V1 Contrast/Coherence Averages



MT Timing Averages



V1 Timing Averages



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. Non-linear response functions were modeled using an exponential: $Response(s) = \alpha - \alpha e^{-\kappa s}$
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 0.064 and 0.016% 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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