Hierarchical effects of contrast and motion coherence in early visual cortex

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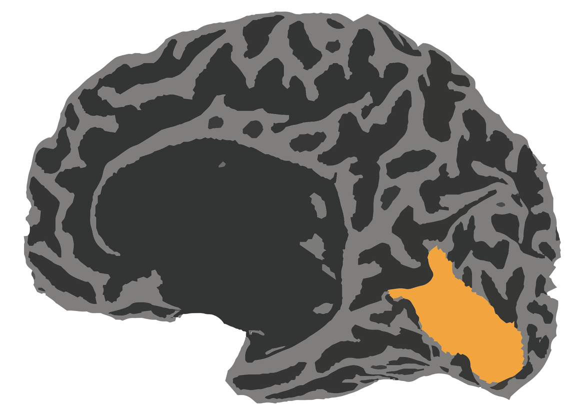
Summary

Using contrast discrimination based on V1 as a “ground truth” we jointly fit the discrimination of motion coherence. Cortical responses in MT, combined with additive neural noise, best explain performance on a motion coherence discrimination task.

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



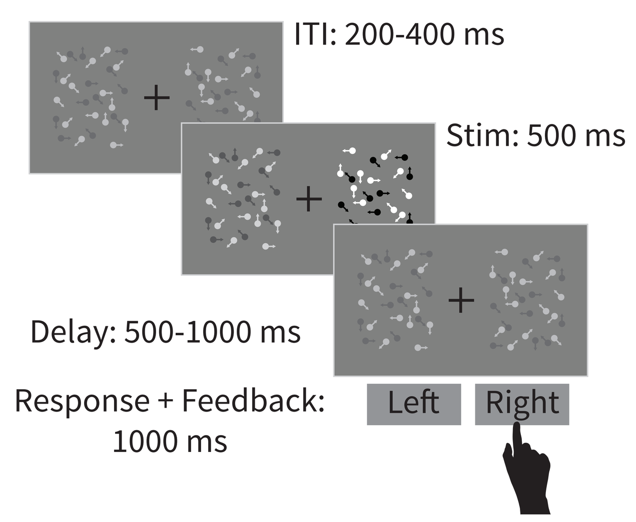
What areas do this for motion coherence?

Task

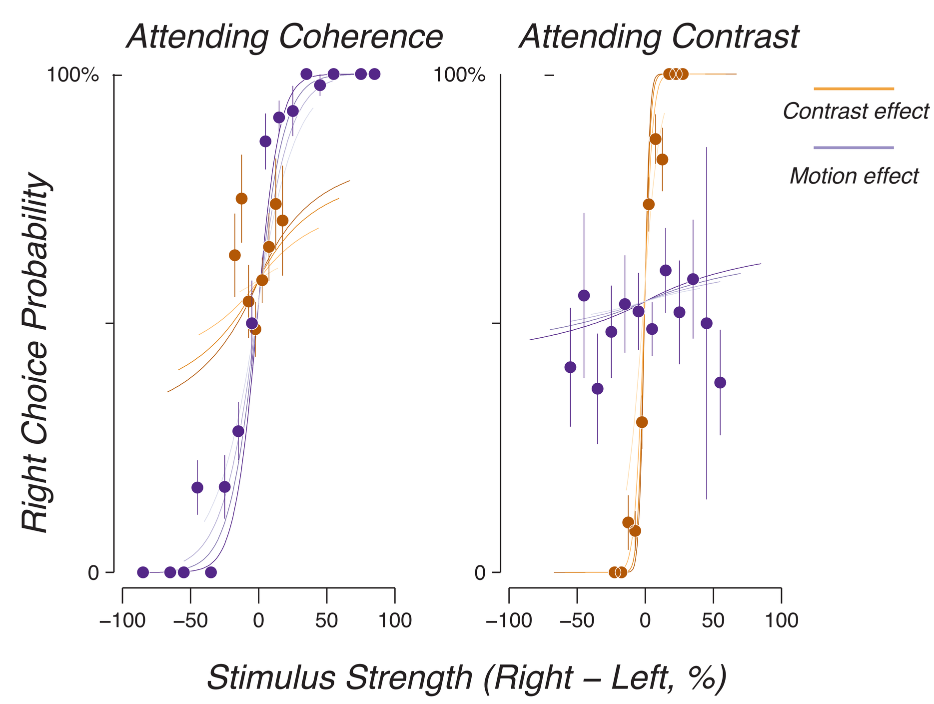
Subjects performed a 2-alternative forced choice discrimination task (mean 1495 trials).

On separate blocks subjects attended contrast or motion coherence.

Discrimination performance was used to constrain stimulus response functions for each feature, modeling the underlying neural responses. The task was modeled as signal detection based on increments in these response functions.

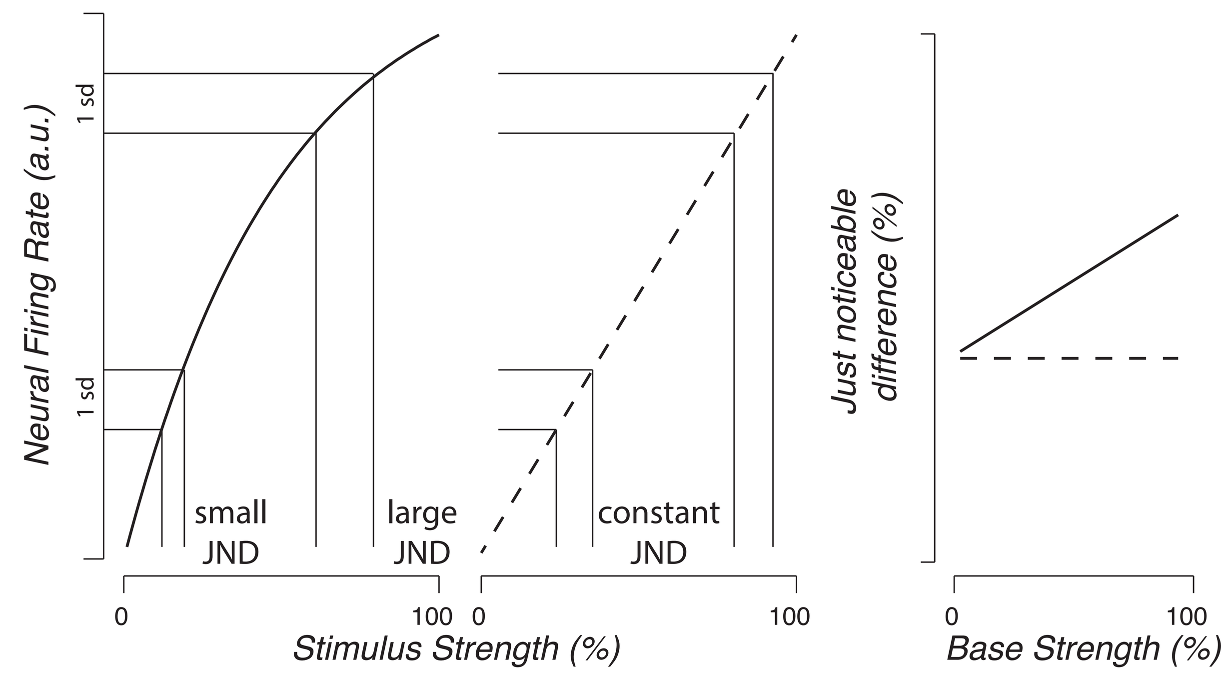


Example subject behavior and model fit

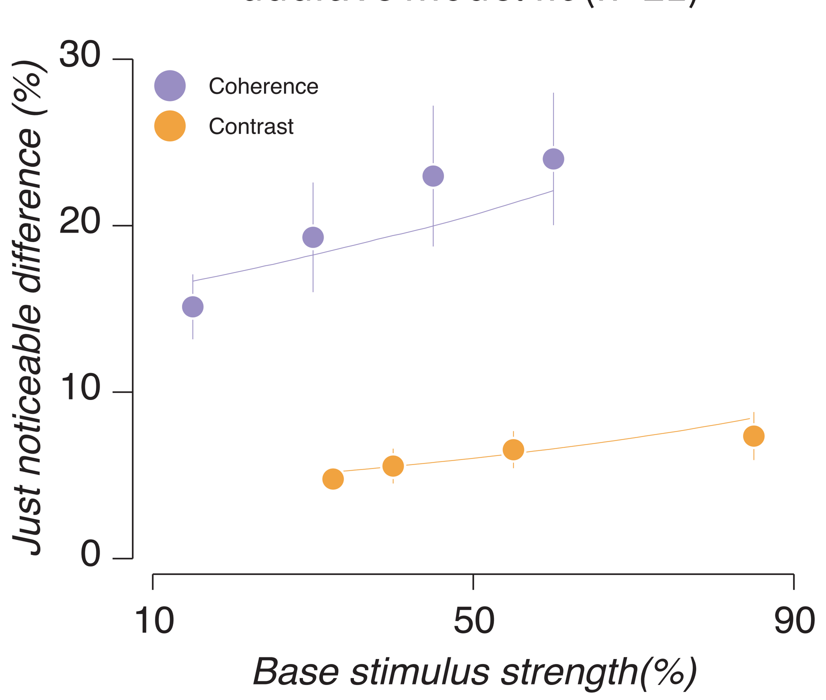


Discrimination performance

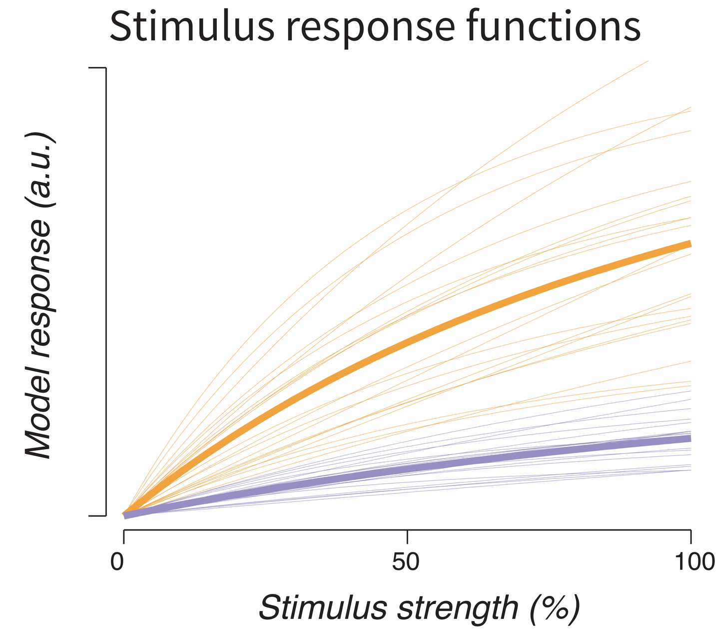
Under additive neural noise a non-linear stimulus response function would result in increasing just noticeable differences as the as stimulus strength increases[2]. Previous work suggests the motion coherence response function is linear[3,4], which would result in constant just noticeable differences.



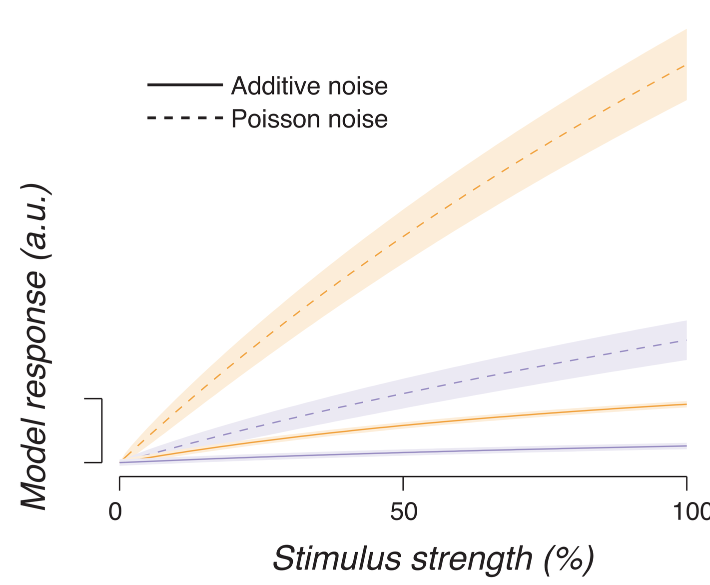
Just noticeable differences and additive model fit (n=21)



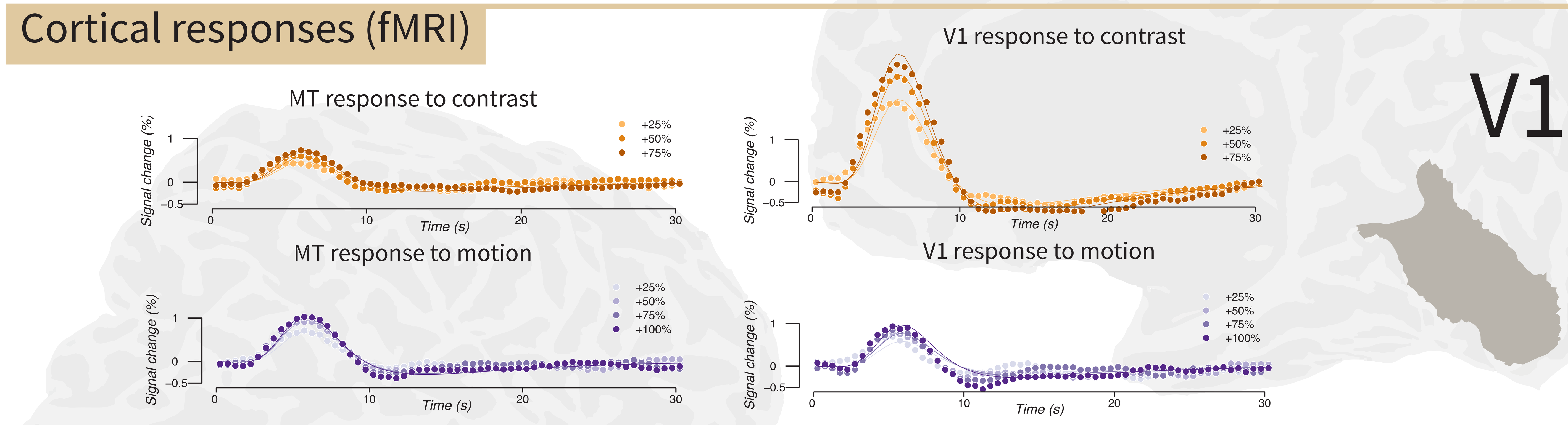
Stimulus response functions



Noise model comparison

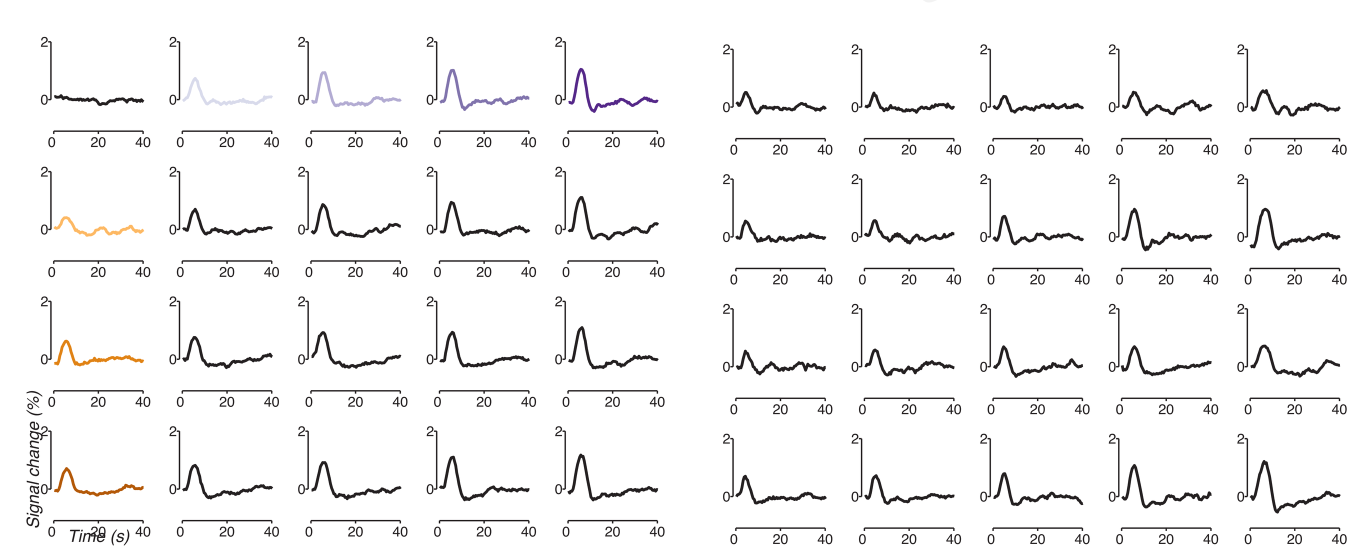


Cortical responses (fMRI)

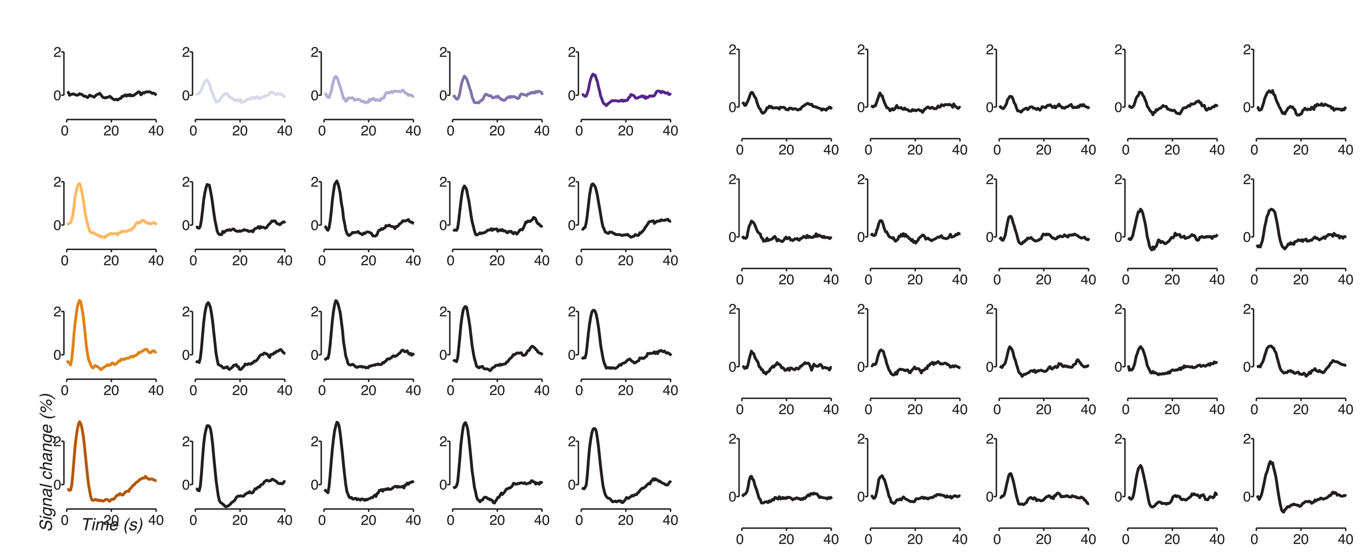


Subjects were shown two patches of dots while fixating. 20 repeats of 40 conditions were recorded with varying contrast, motion coherence, and trial length (see below). Example cortical responses are shown above for V1 and MT from a small slice of the data.

Average responses for MT in all conditions (n=11)



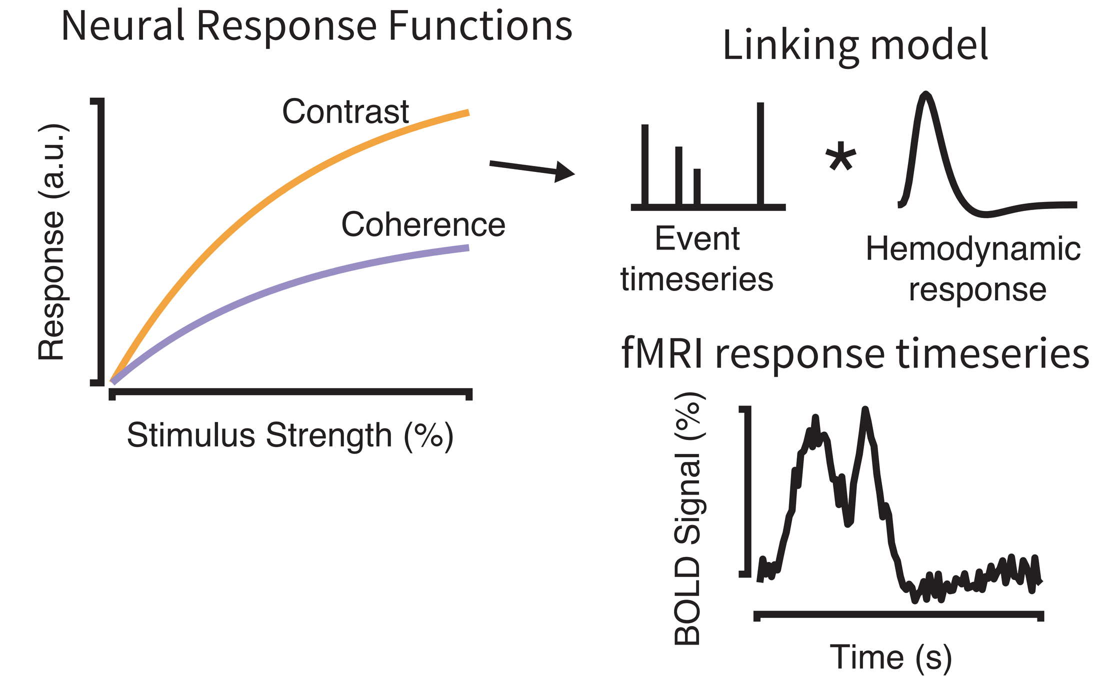
Average responses for V1 in all conditions (n=11)



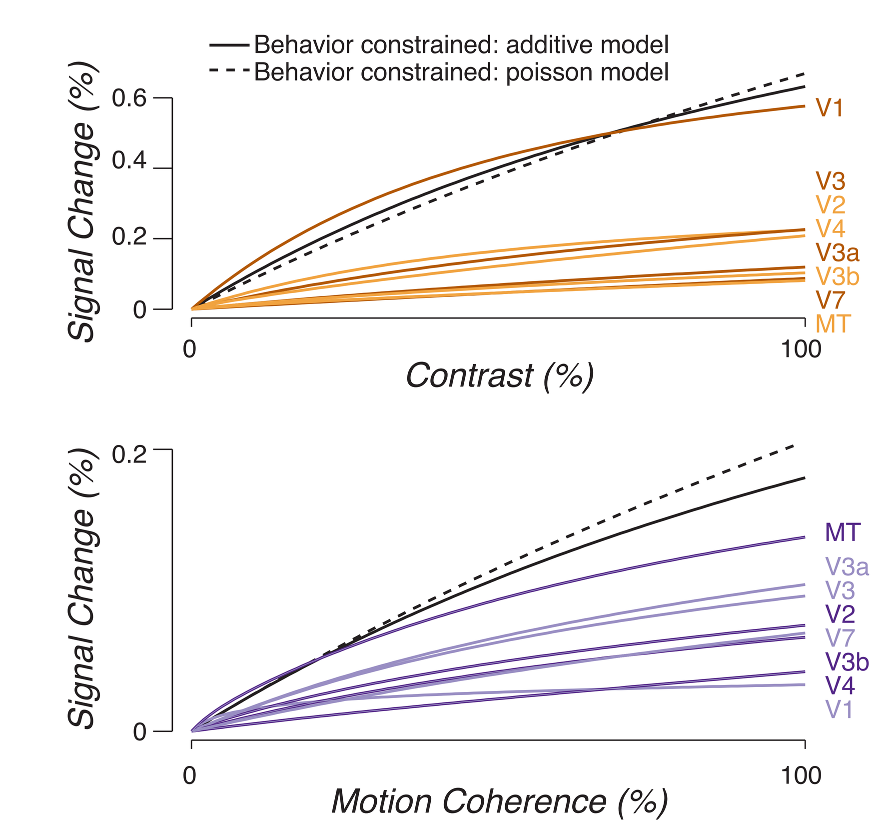
Linking model

Cortical responses were used to constrain stimulus response functions. The amount of neural noise[5] was fit using V1 to constrain the contrast response function: under additive noise 0.035%, poisson: 0.005%.

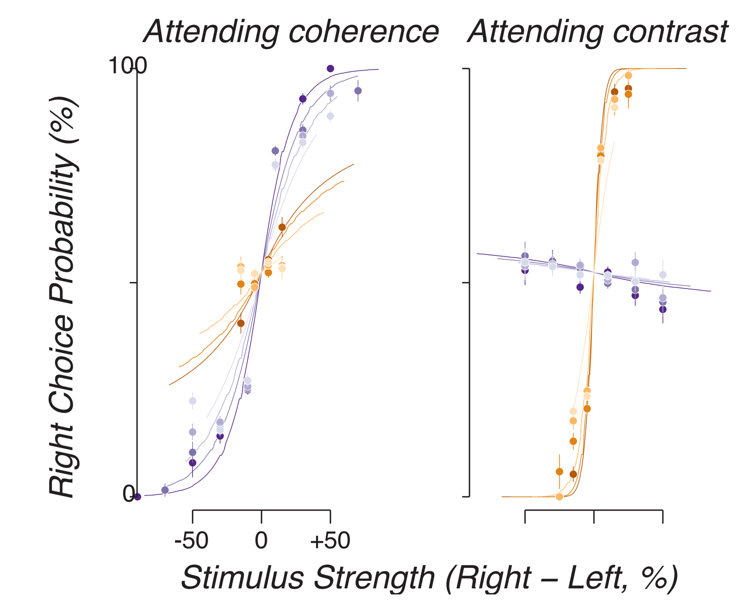
Neural Response Functions



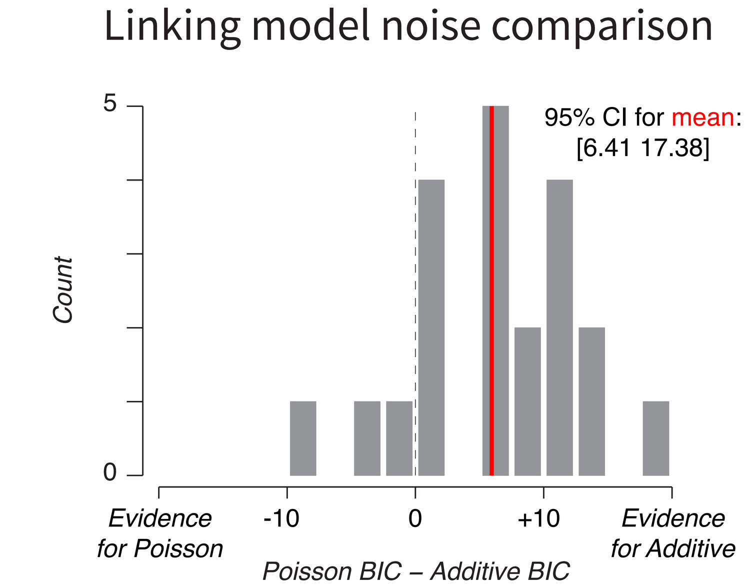
fMRI and behavioral constrained stimulus response functions[5]



Cortical response fit to behavior



Linking model noise comparison



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 a non-linear MT cortical response to increasing motion coherence.

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. Response functions were modeled using an exponential function : $Response(s) = -\alpha e^{-\kappa s}$

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 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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