Hierarchical Effects of Contrast and Motion Coherence in Early Visual Cortex

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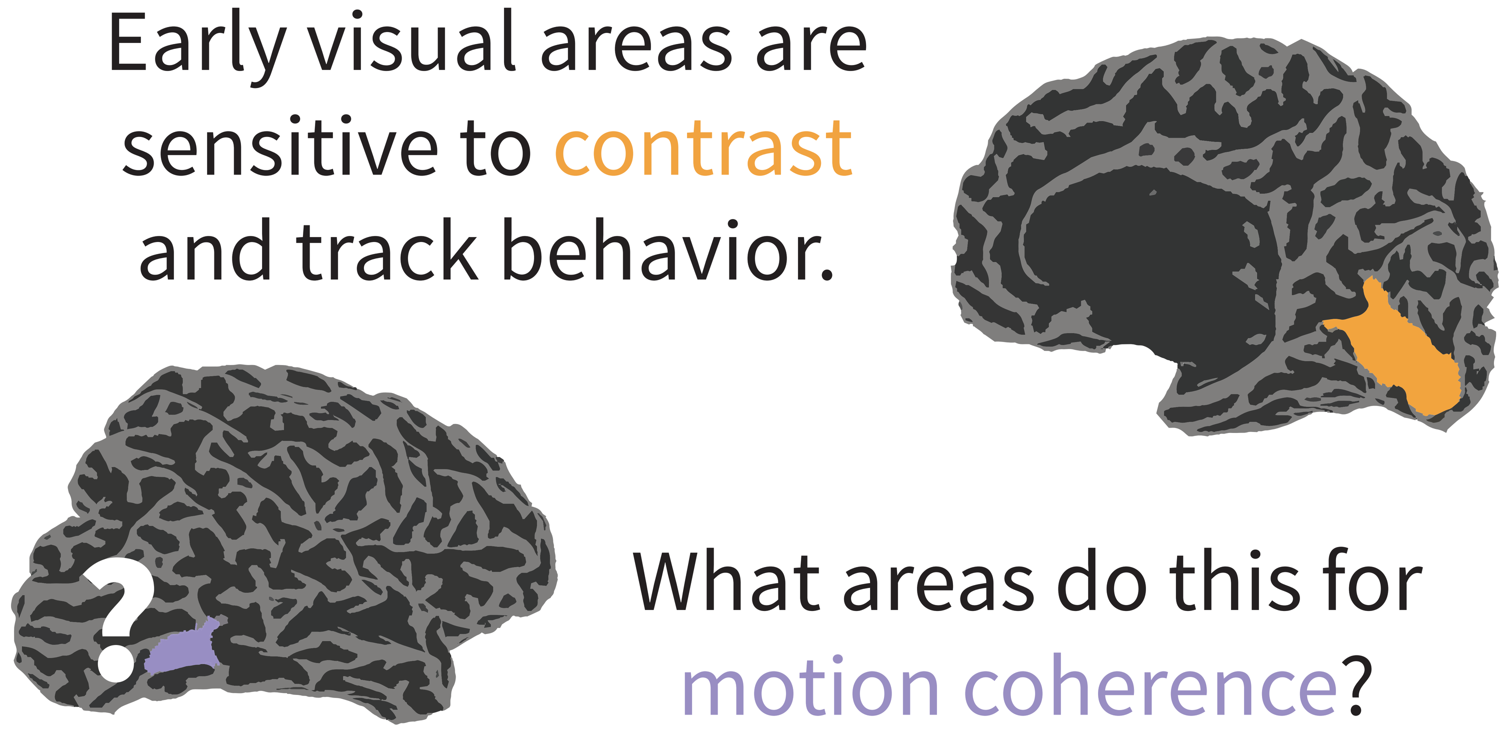
Summary

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.

We found that cortical responses in MT are of sufficient magnitude to explain performance on a motion coherence discrimination task.

Early visual areas are sensitive to contrast and track behavior.

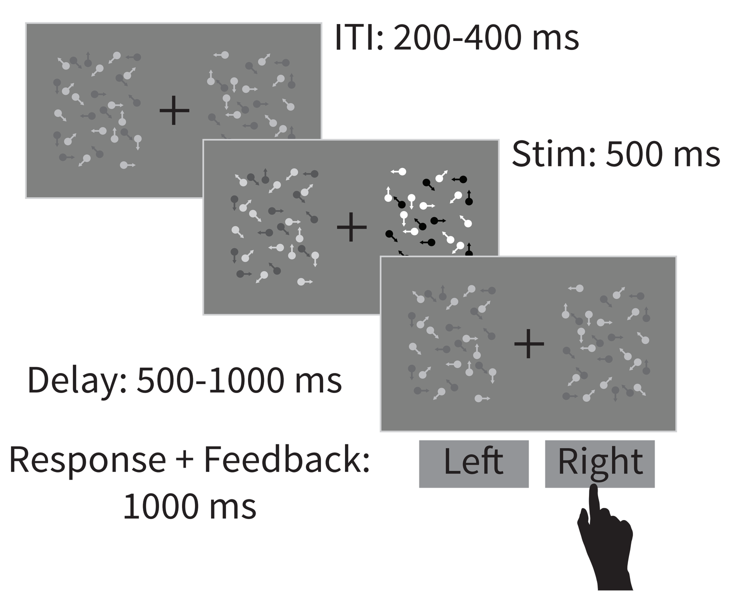


What areas do this for motion coherence?

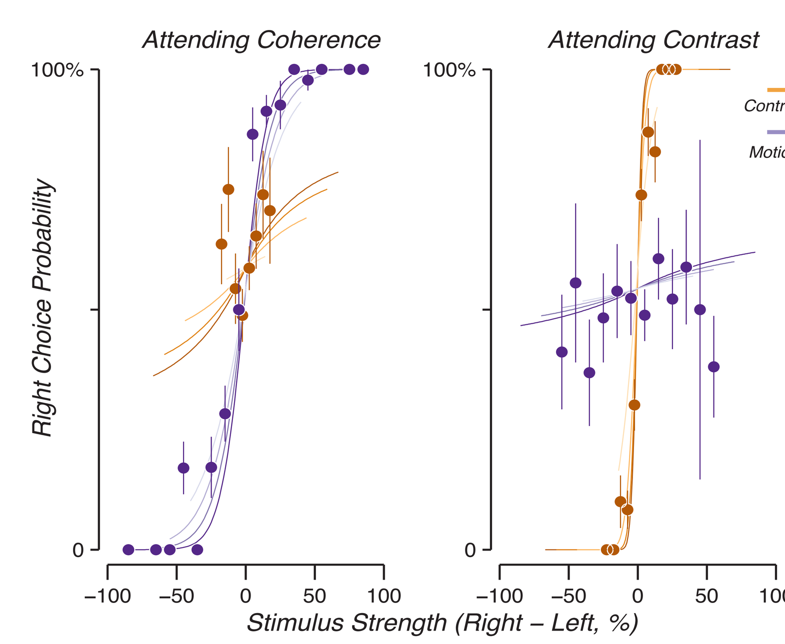
Task

Behavior was collected from subjects performing a 2-alternative forced choice discrimination task (median 1490 trials). 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% contrast 0% coherence until each trial began.

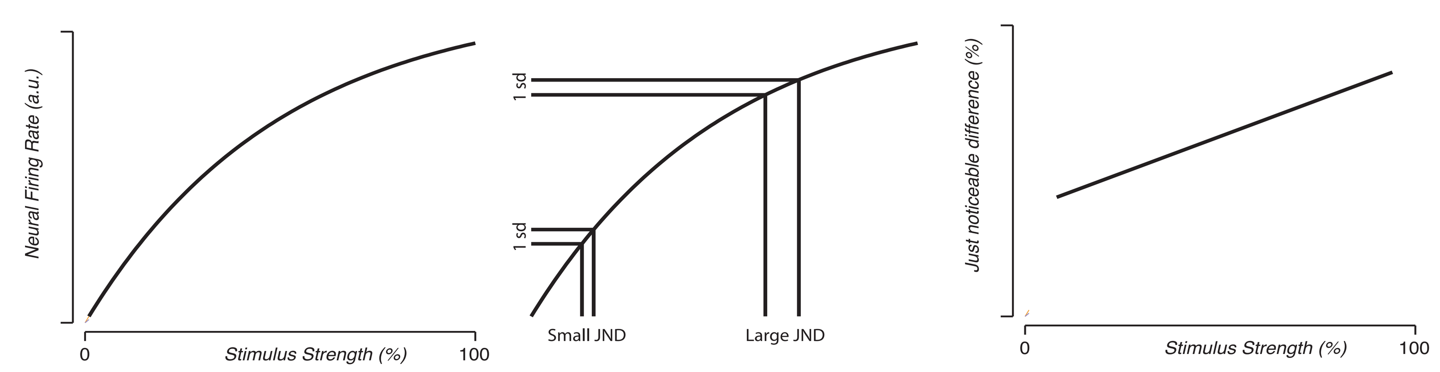


Example subject behavior and behavioral model fit

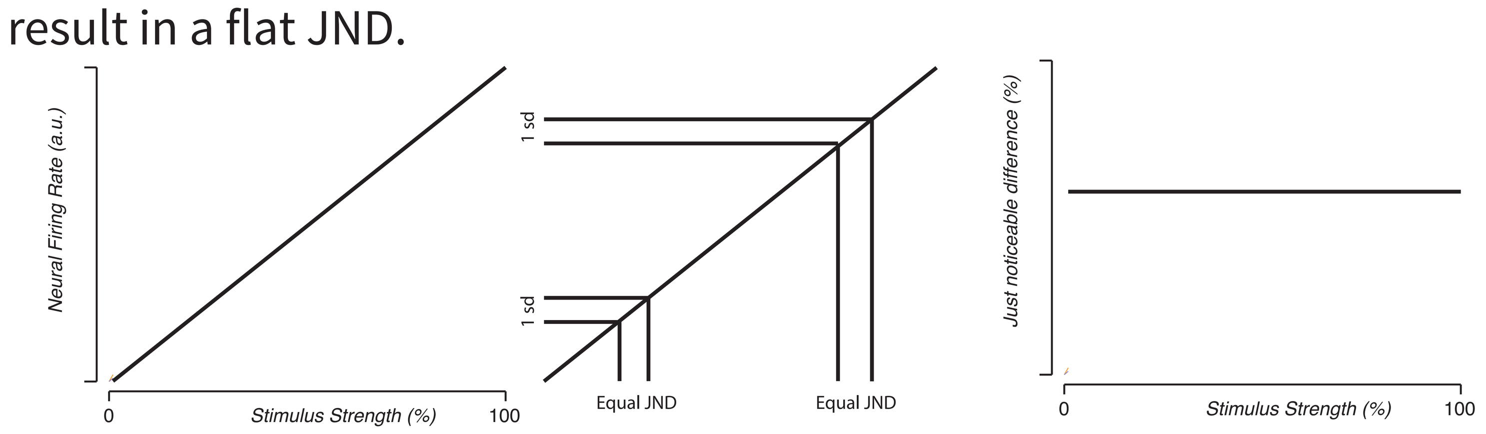


Discrimination performance

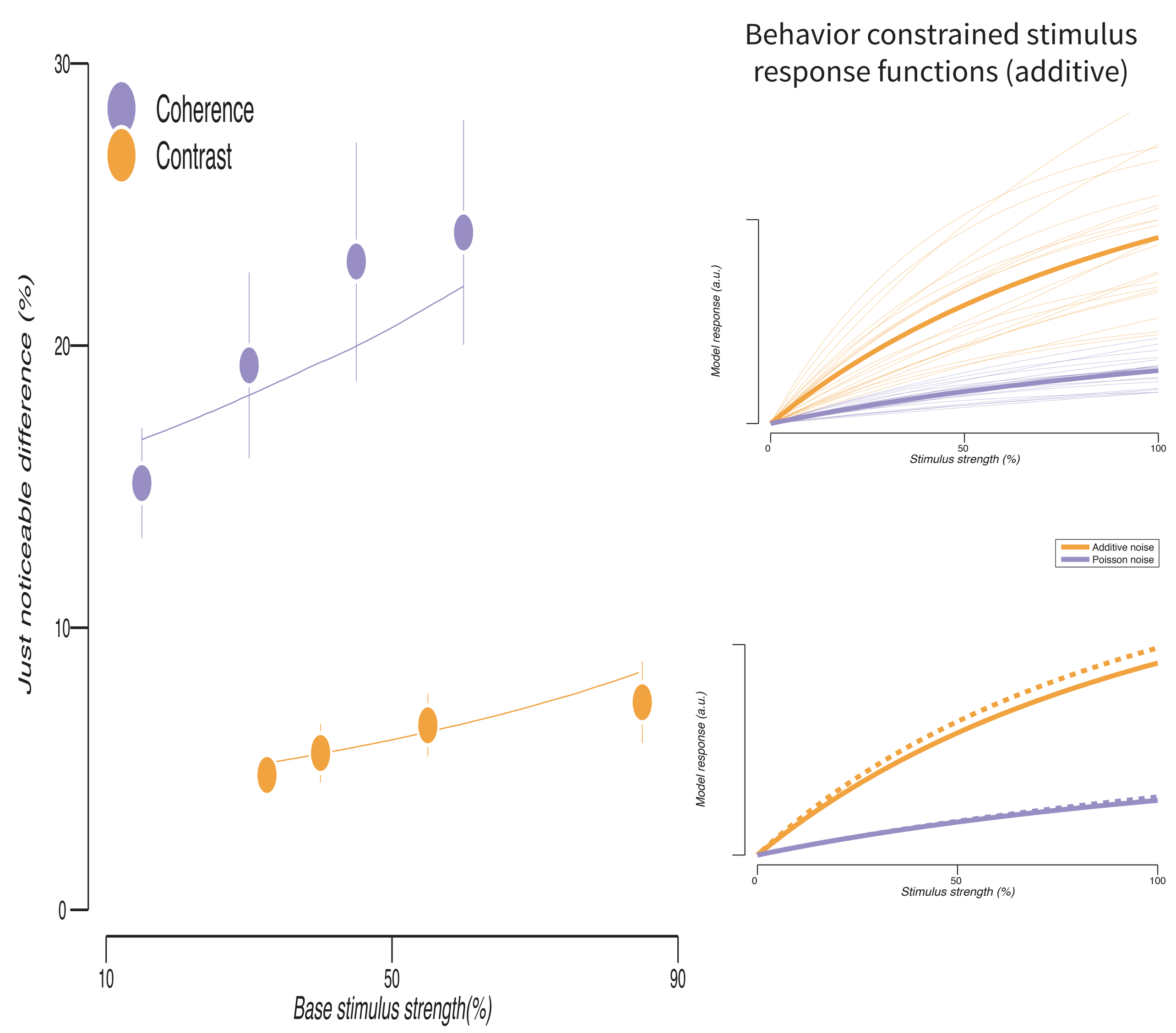
Subjects' "just noticeable difference" (JND) increases with base stimulus strength, as expected[1] if a non-linear neural response is used to perform signal detection.



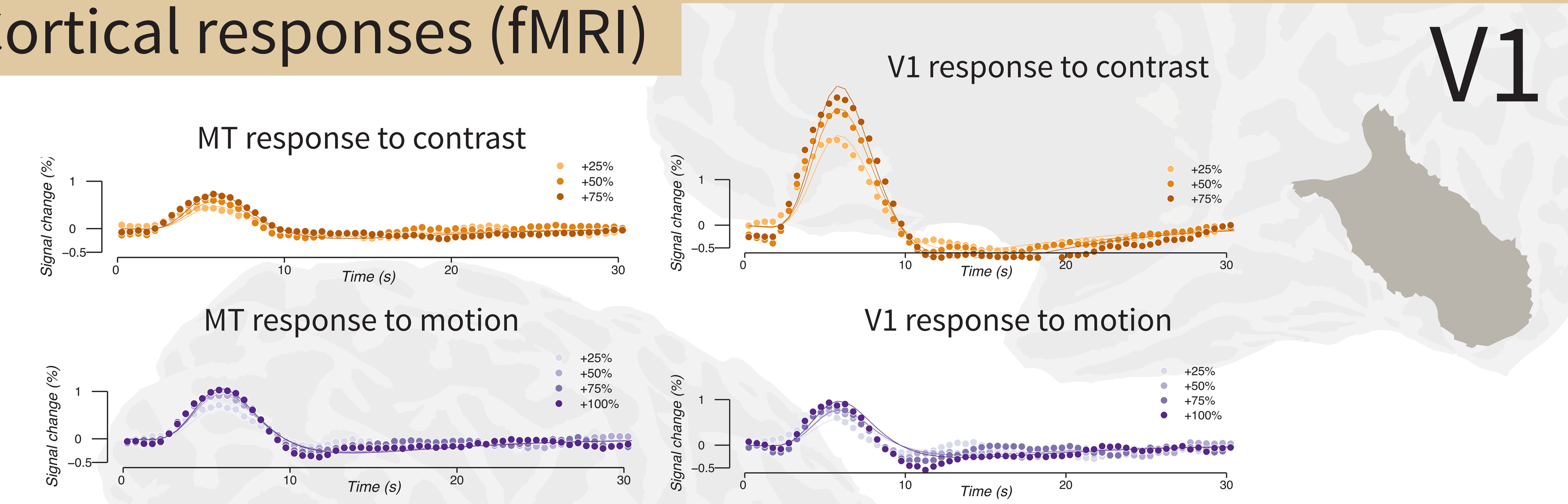
But previous work has suggested that the neural response to motion coherence is *linear*[2,3], which, under conditions of additive noise, would result in a flat JND.



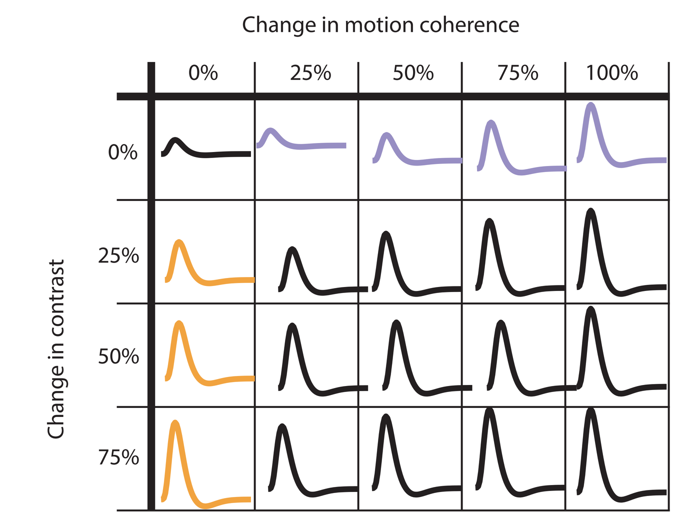
Just noticeable differences for contrast and motion coherence discrimination



Cortical responses (fMRI)

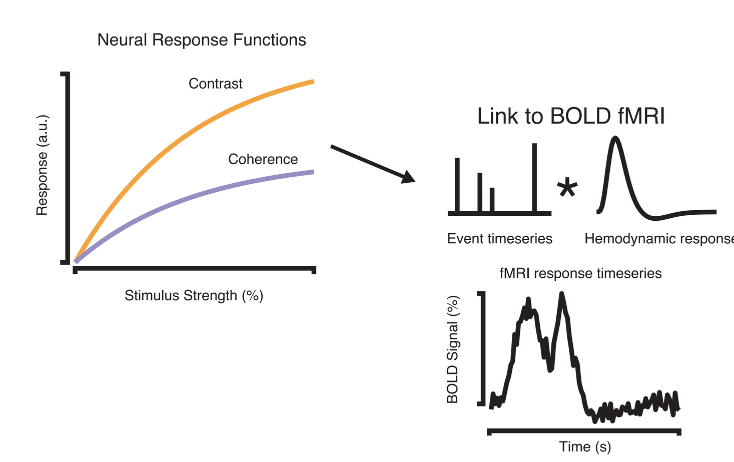


Example cortical responses are shown for V1 and MT in the constant contrast and motion coherence conditions. The linking model was constrained using all of the available data.

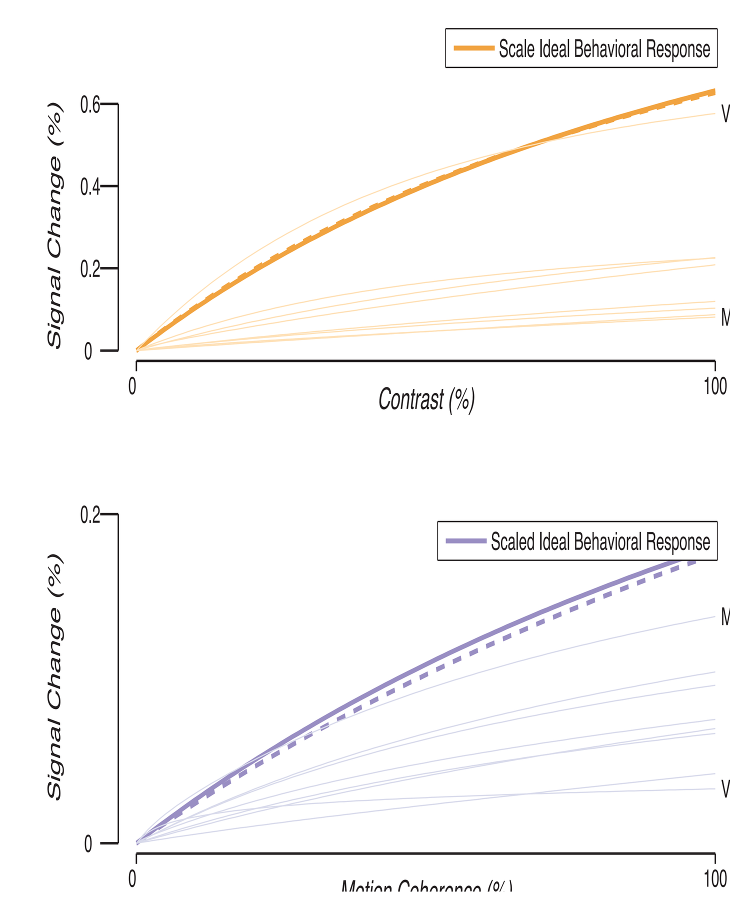


Linking model

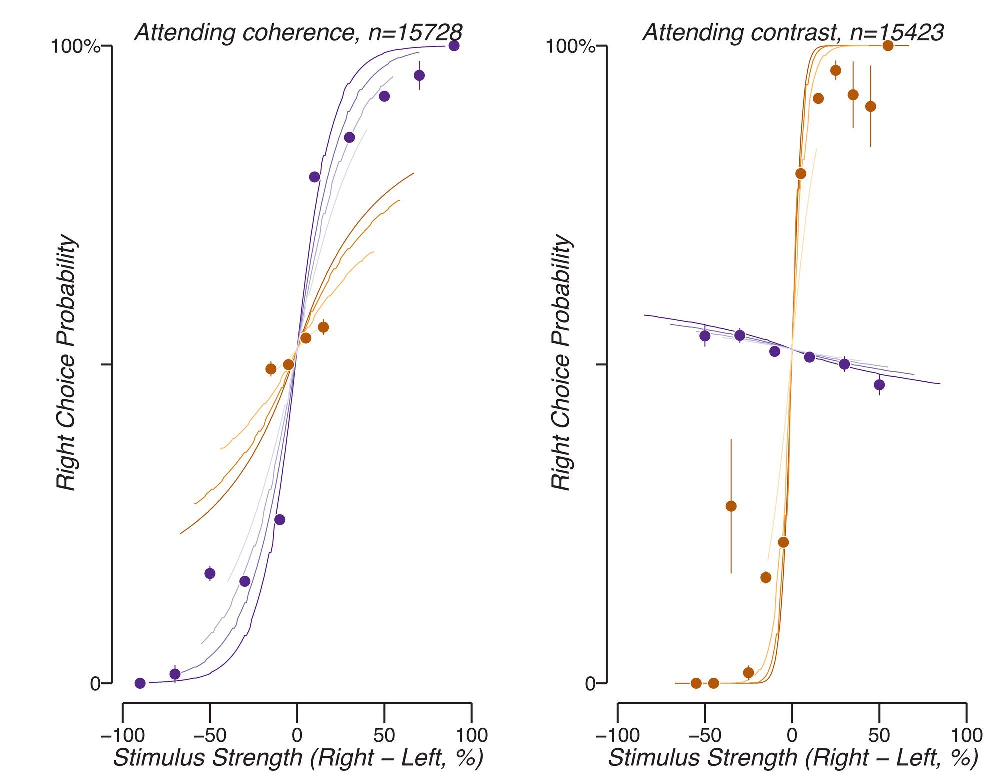
Cortical responses were used to constrain stimulus response functions by convolving event-related response magnitudes with a canonical hemodynamic response function. The amount of neural noise was fit as a free parameter. Under additive noise: 0.035%, poisson: 0.031%



fMRI constrained stimulus response functions[5]



Behavioral fit using cortical response functions and additive noise



Poisson BIC:

Additive BIC:

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.

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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