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].

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.
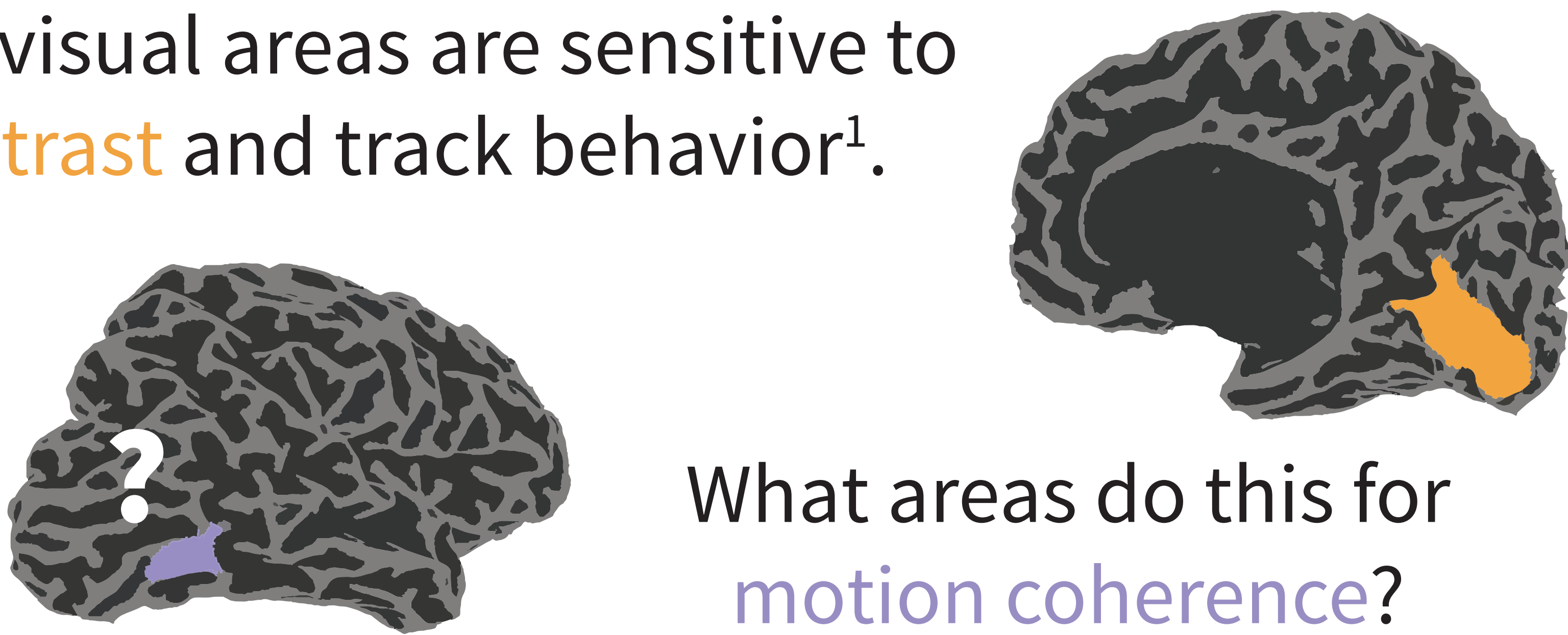
What areas do this for motion coherence?

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.
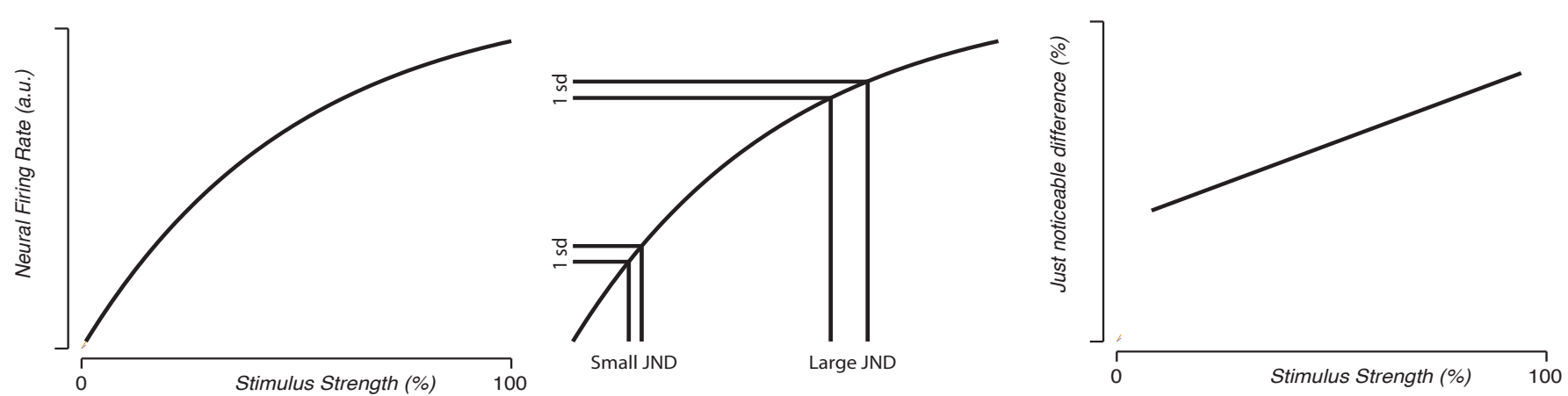

ITI: 200-400 ms
Stim: 500 ms
Delay: 500-1000 ms
Response + Feedback: 1000 ms
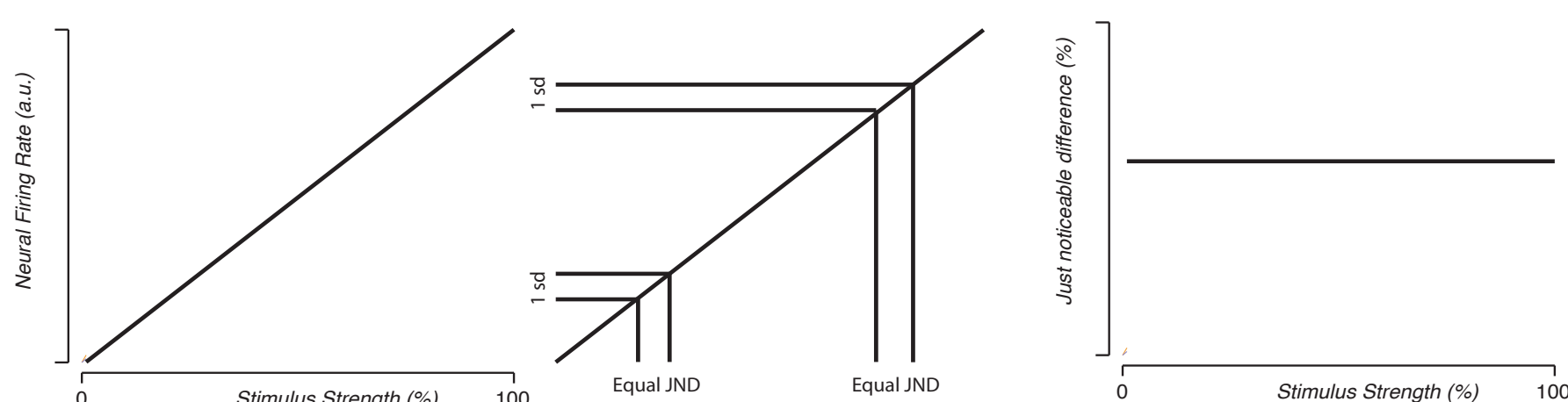Left | Right
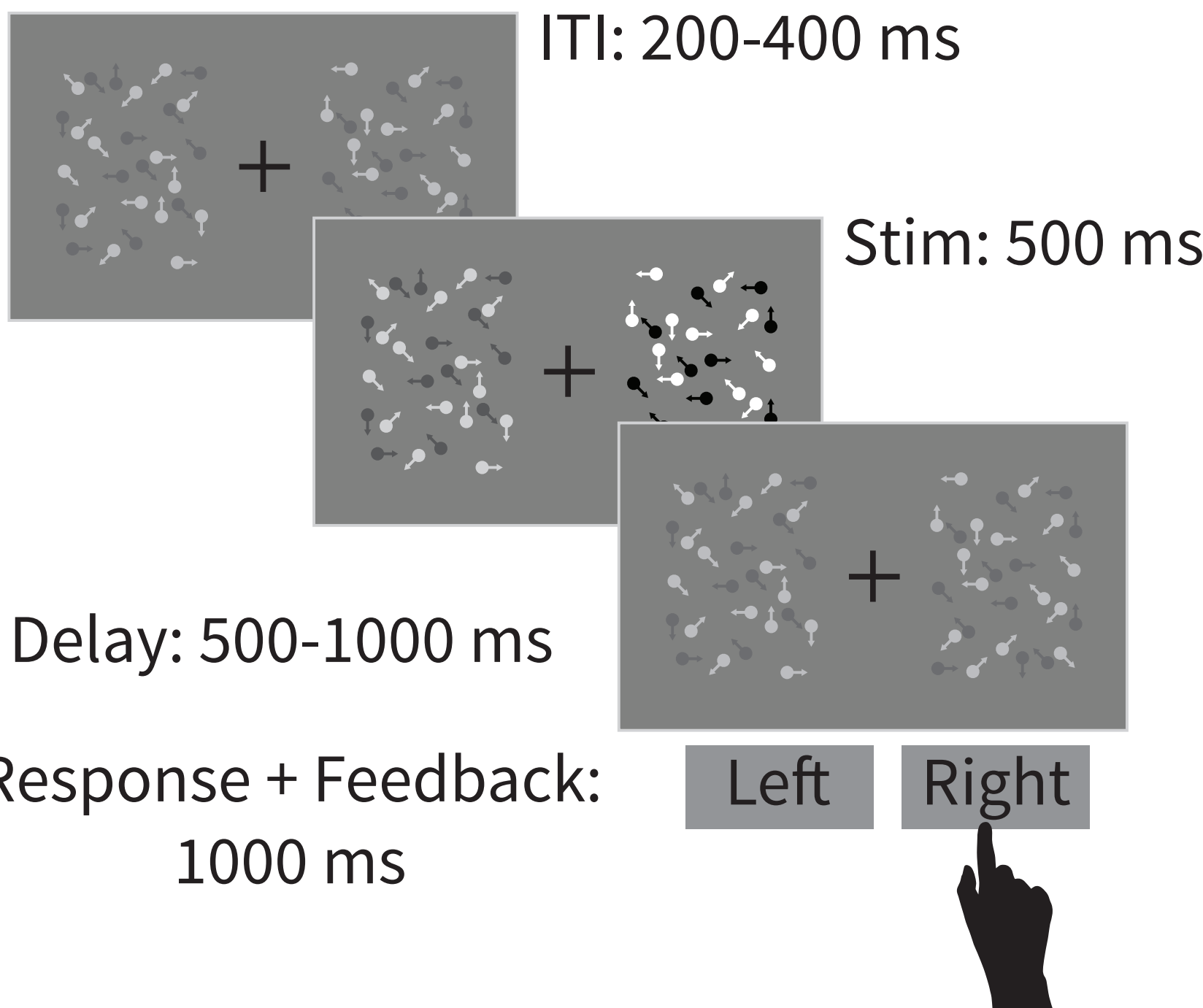
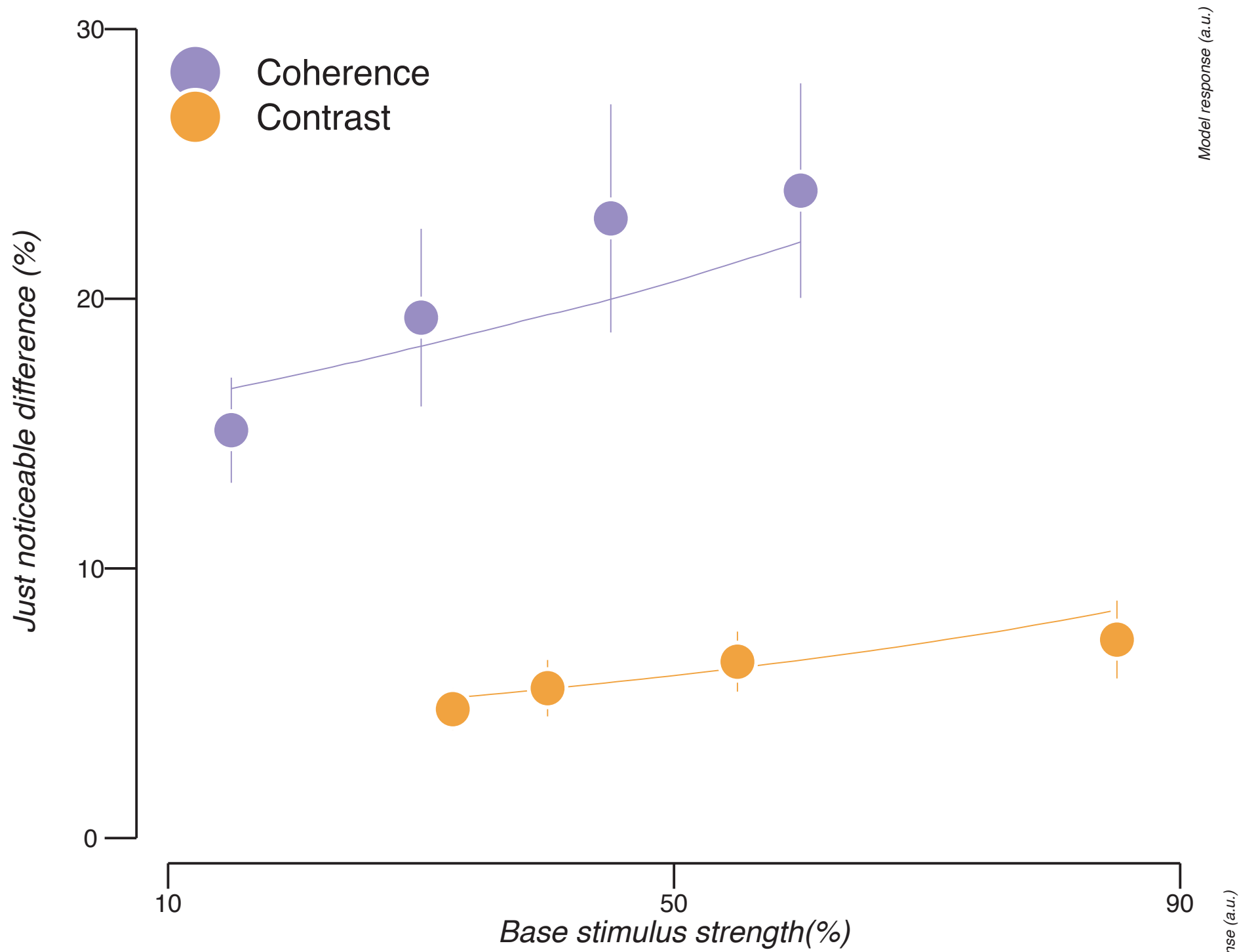Example subject behavior and model fit
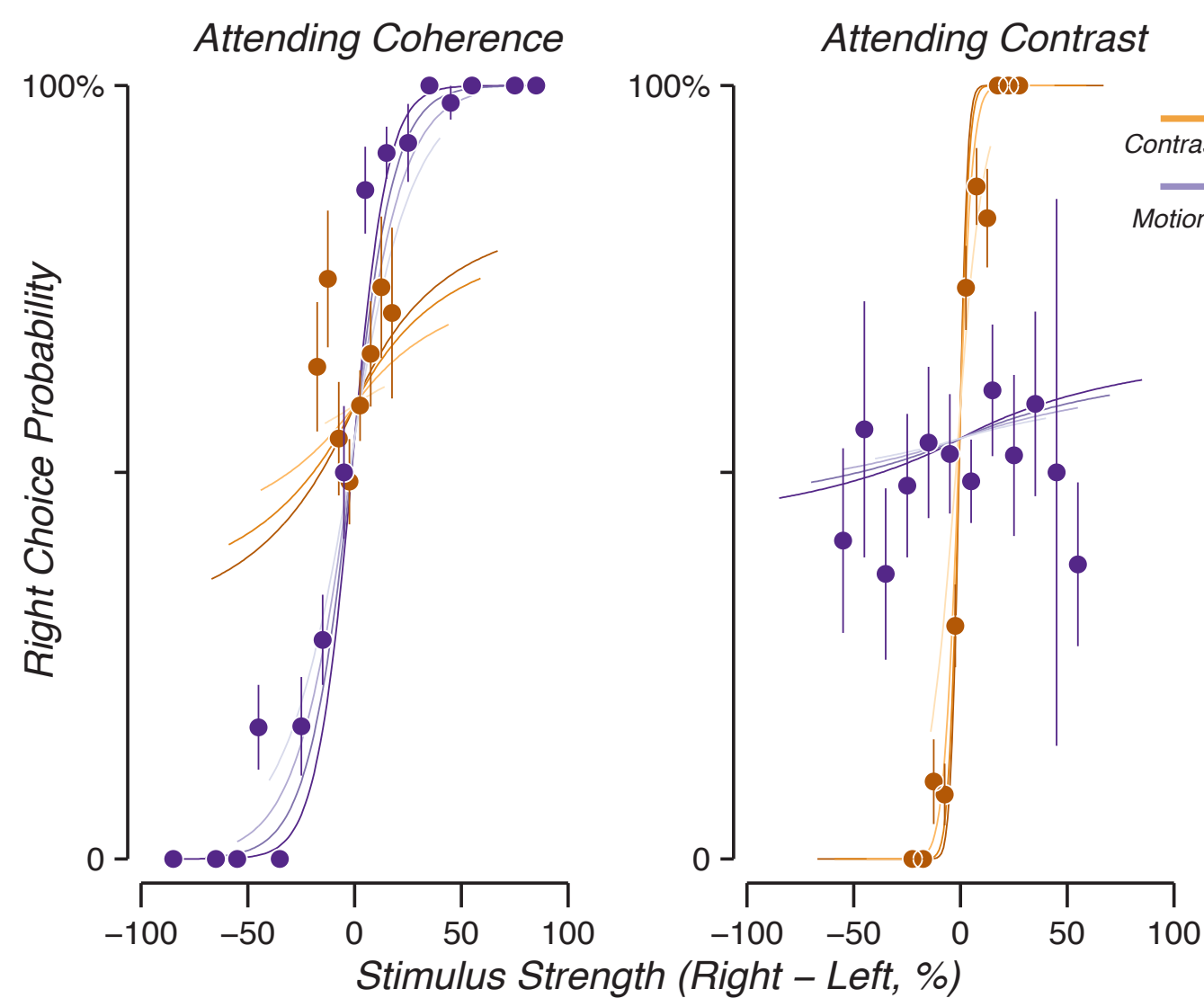
Discrimination performance

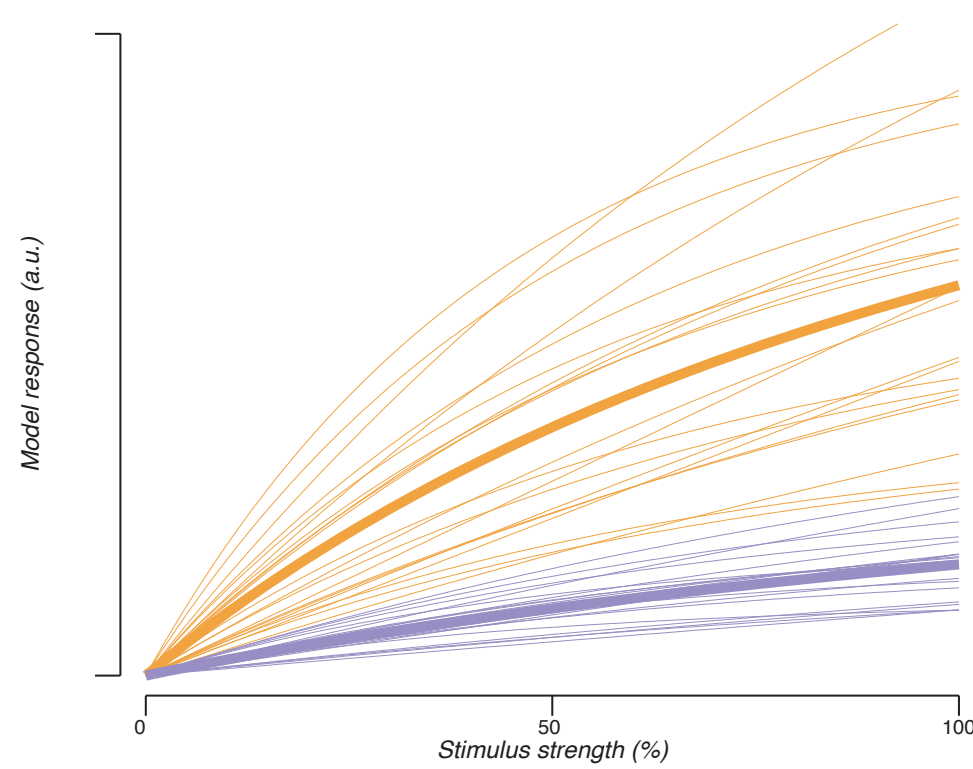Under additive neural noise an increasing just noticeable difference indicates a non-linear stimulus response function[2].

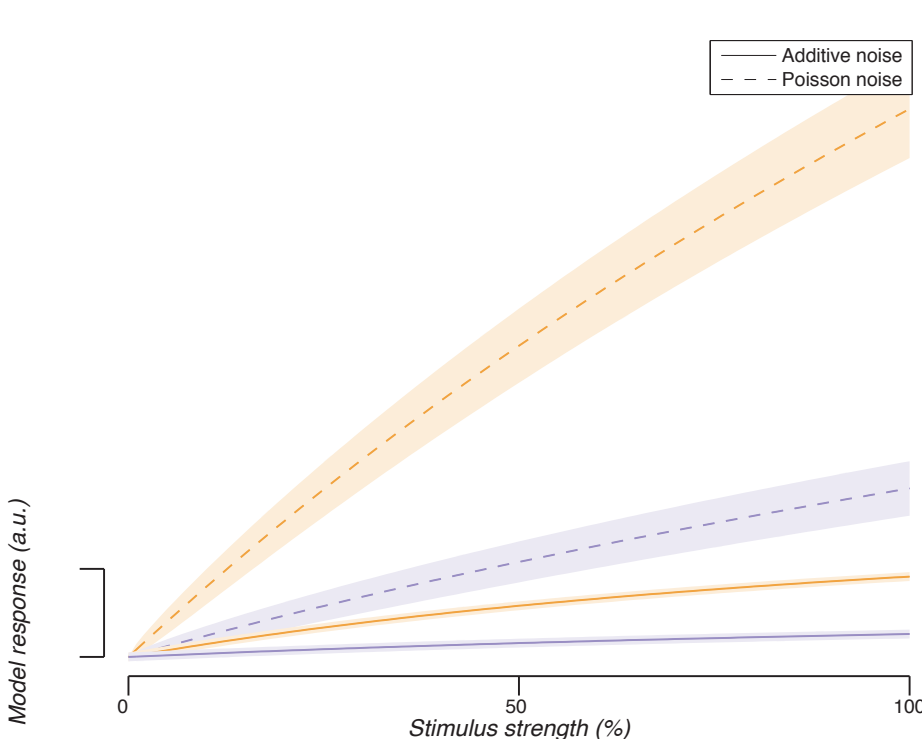Previous work suggests the motion coherence response function is linear[3,4].

Just noticeable differences and model fit (n=21)
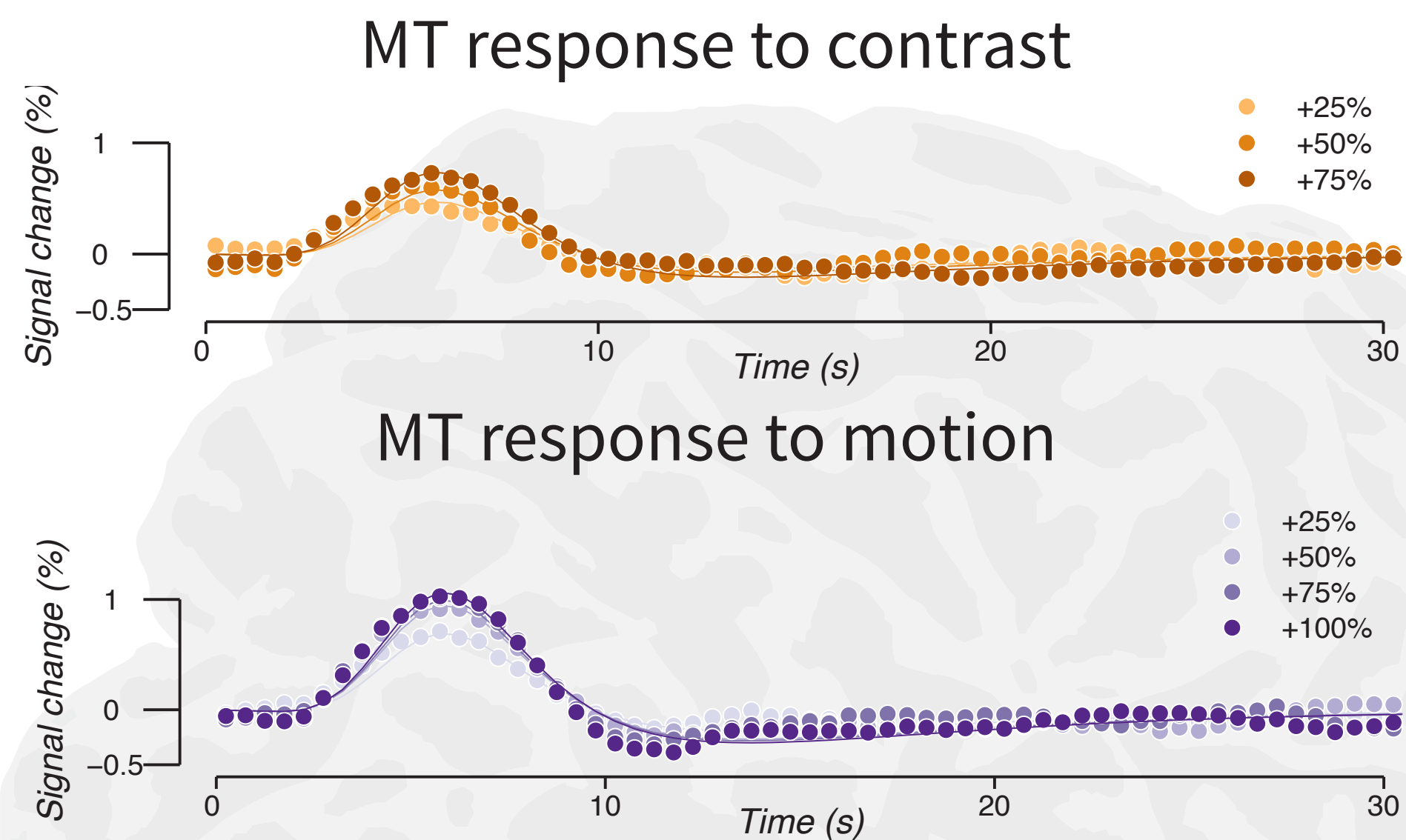
- Coherence
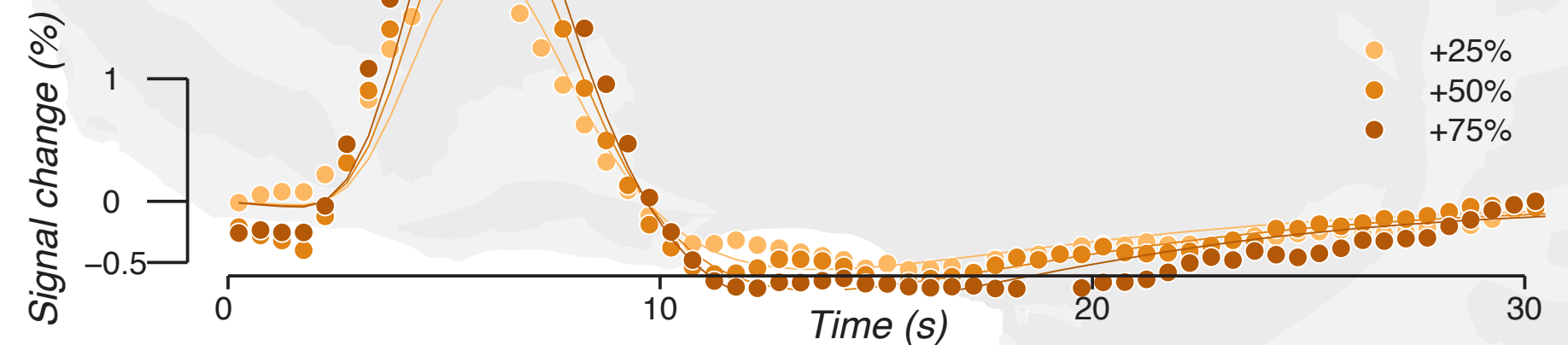- Contrast

Behavior constrained stimulus response functions (additive noise)

Average stimulus response functions for additive and poisson noise

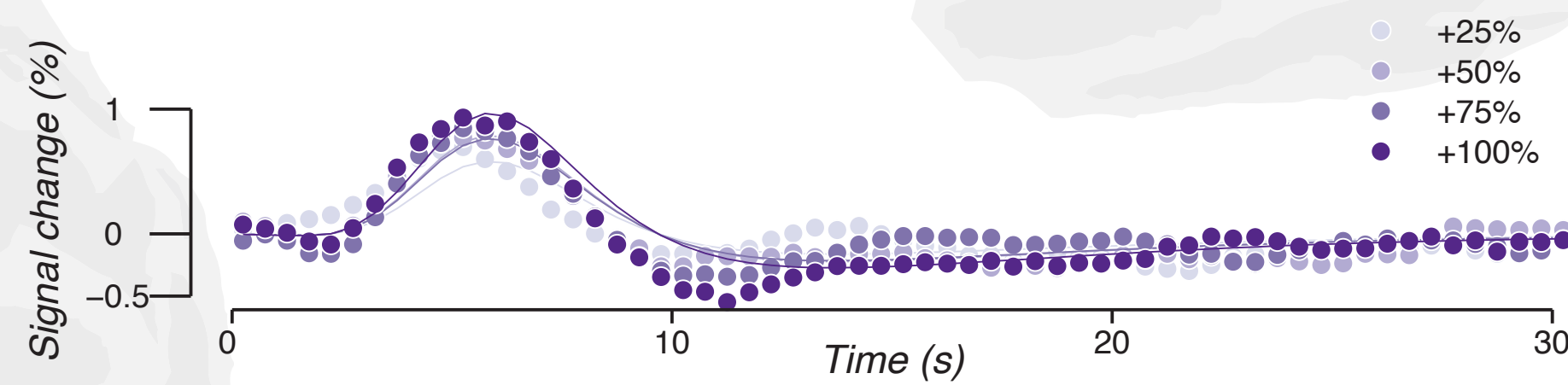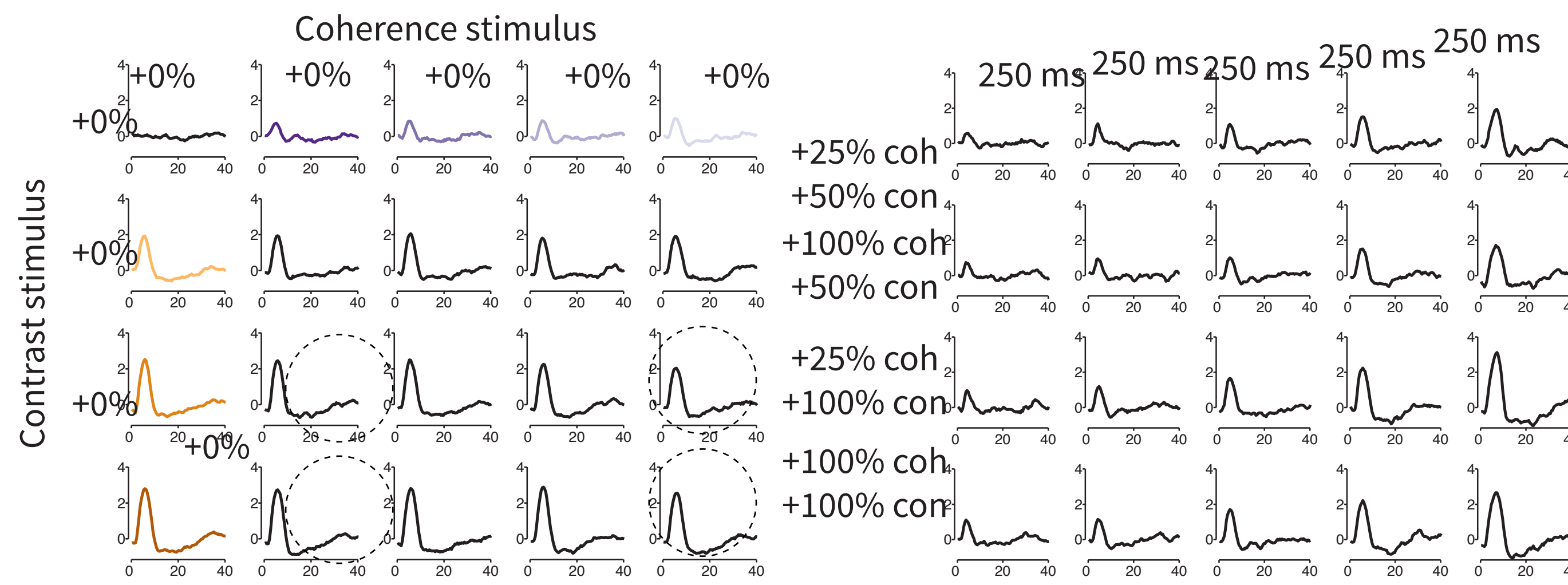## Cortical responses (fMRI)

MT response to contrast
+25% +50% +75%

MT response to motion
+25% +50% +75% +100%

V1 response to contrast
+25% +50% +75%

V1 response to motion
+25% +50% +75% +100%

V1
MT

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

Example cortical responses shown for V1 and MT from a small slice of the data. The linking model was constrained using all of the data.
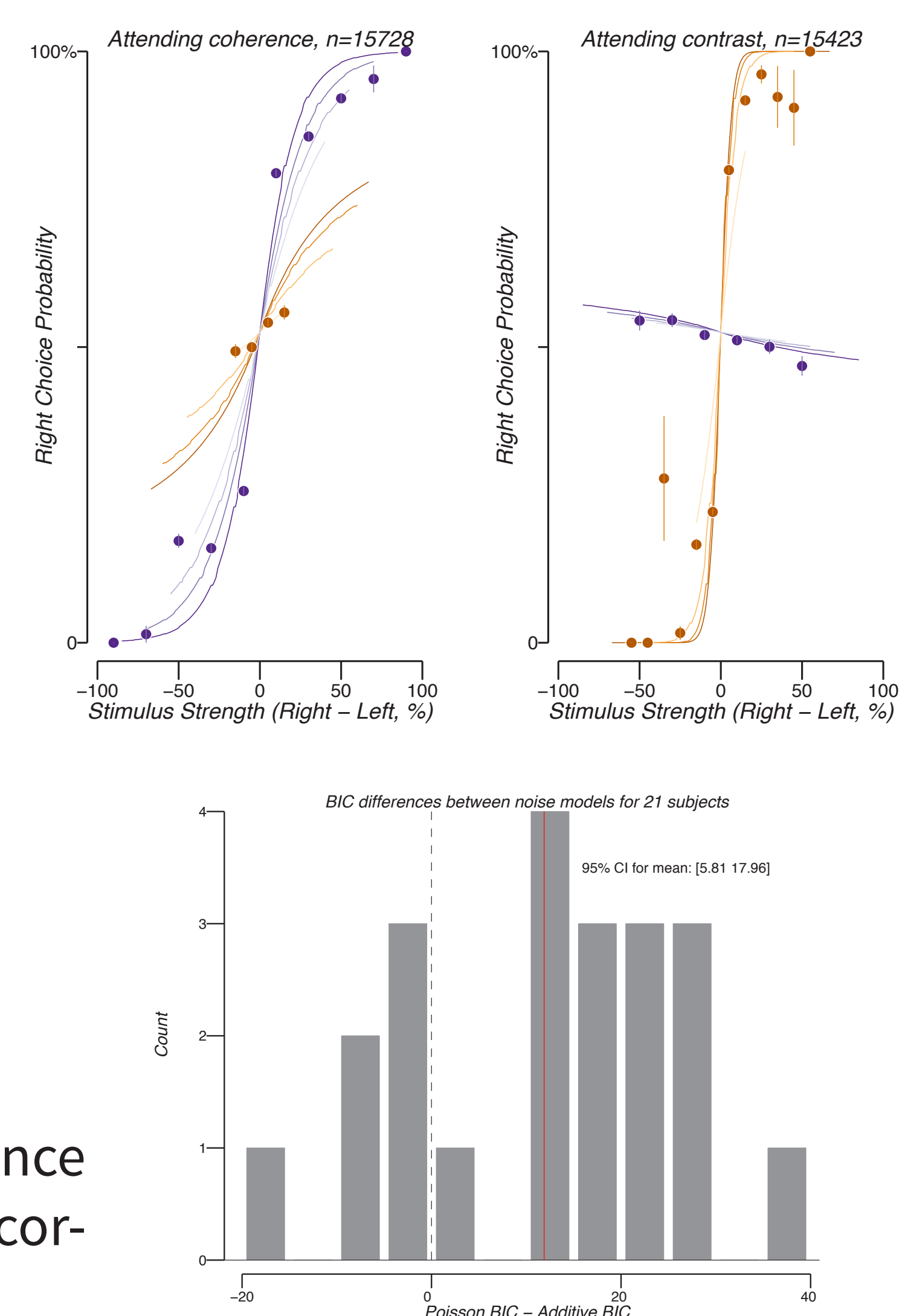
Linking model

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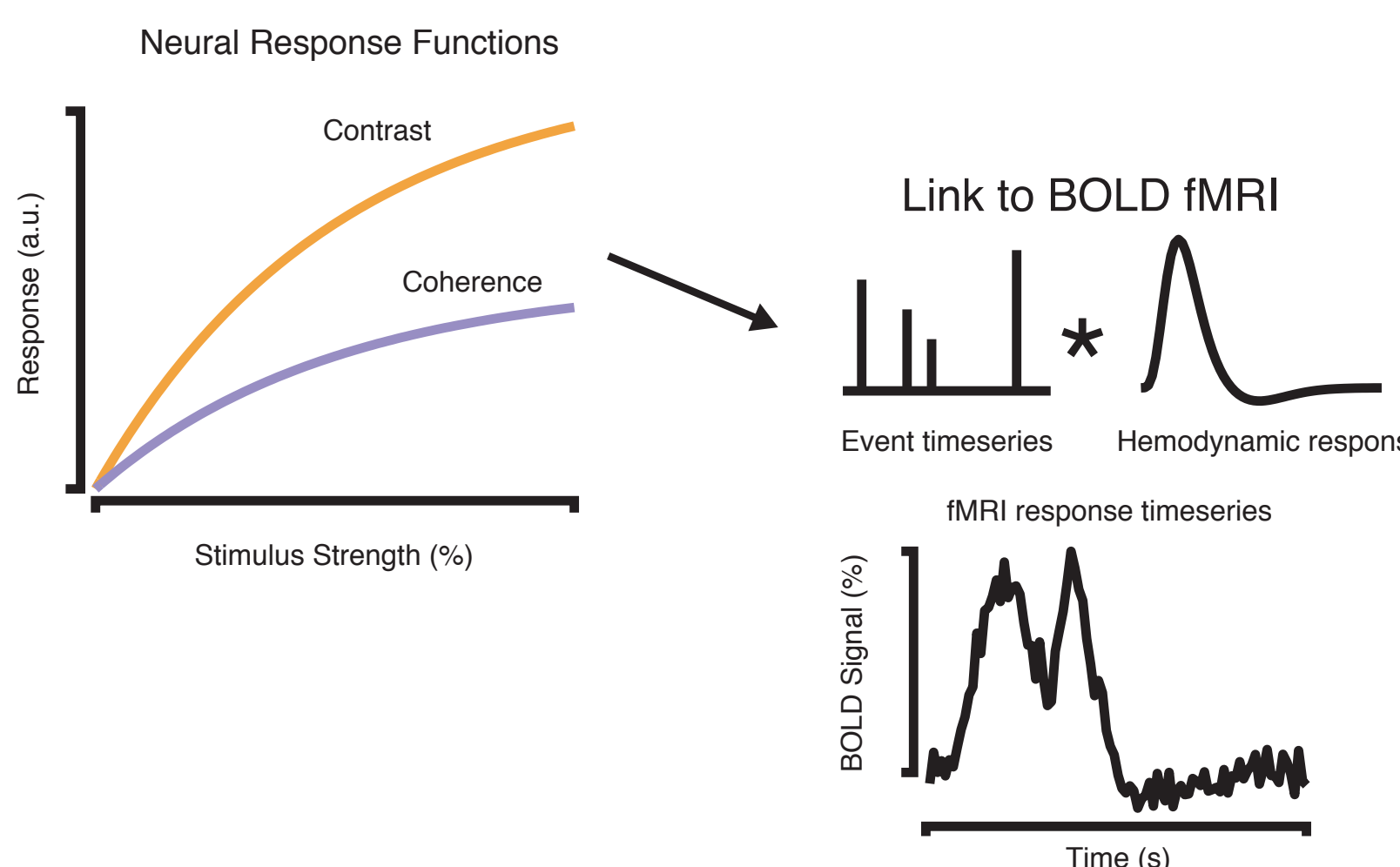
fMRI and behavioral constrained stimulus response functions[5]
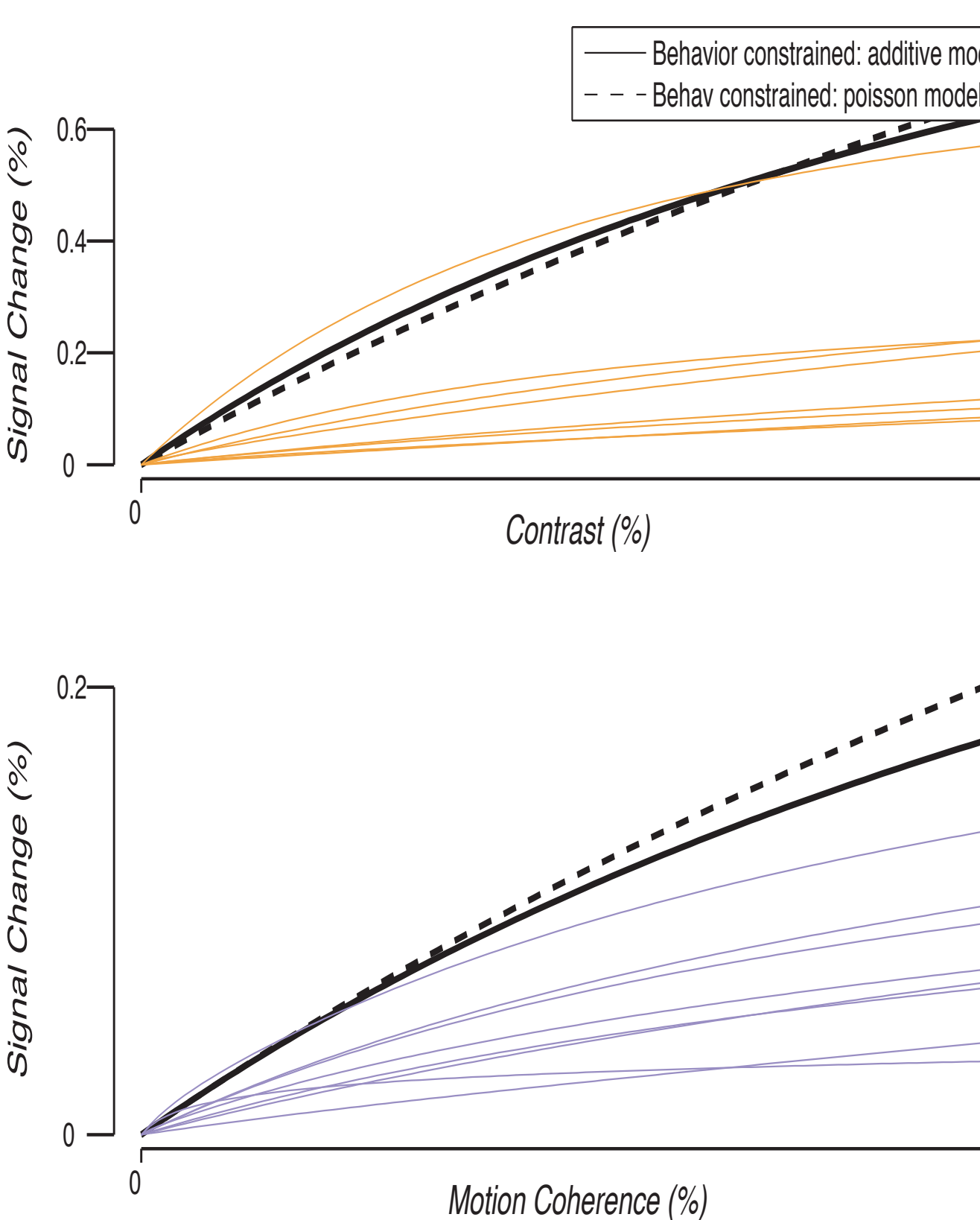
Behavioral fit using cortical response functions and additive noise

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 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. ???
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.

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

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