Hierarchical effects of contrast and motion coherence in early visual cortex

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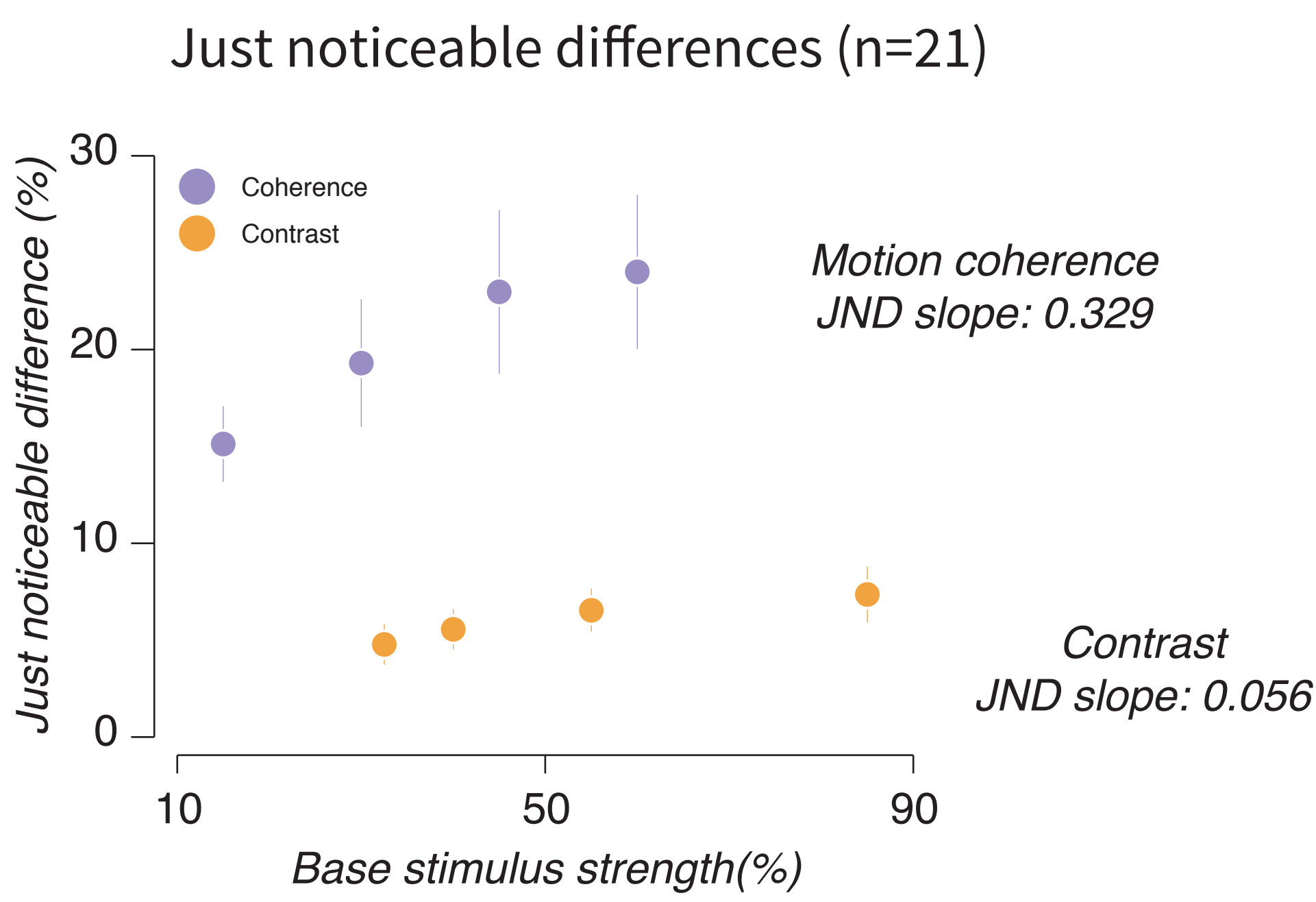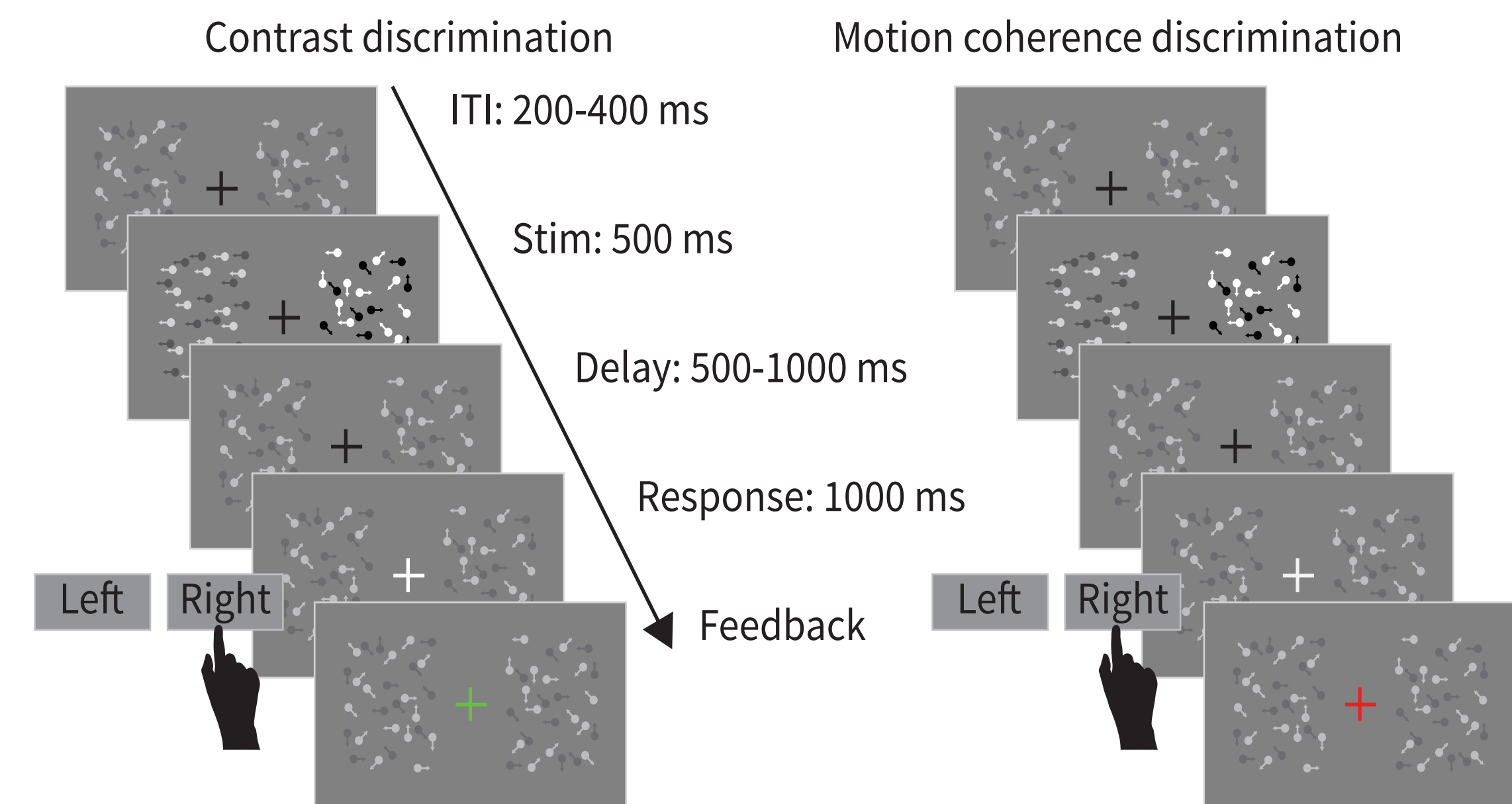danbirman@stanford.edu

1. Introduction

An existing model of contrast discrimination suggests early visual cortex is sufficient to explain behavioral performance[1].
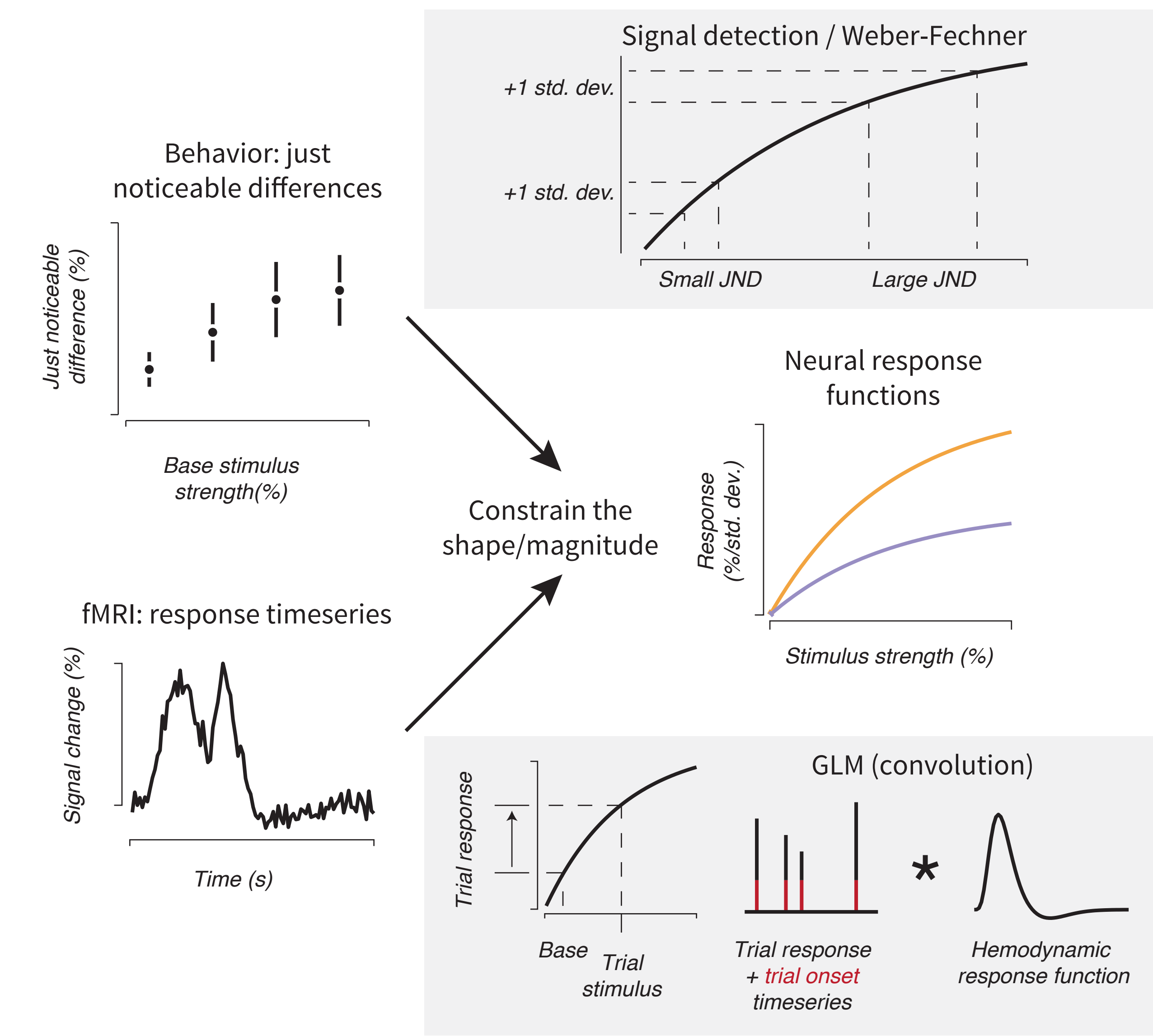
Can that approach be used to jointly explain motion coherence discrimination?
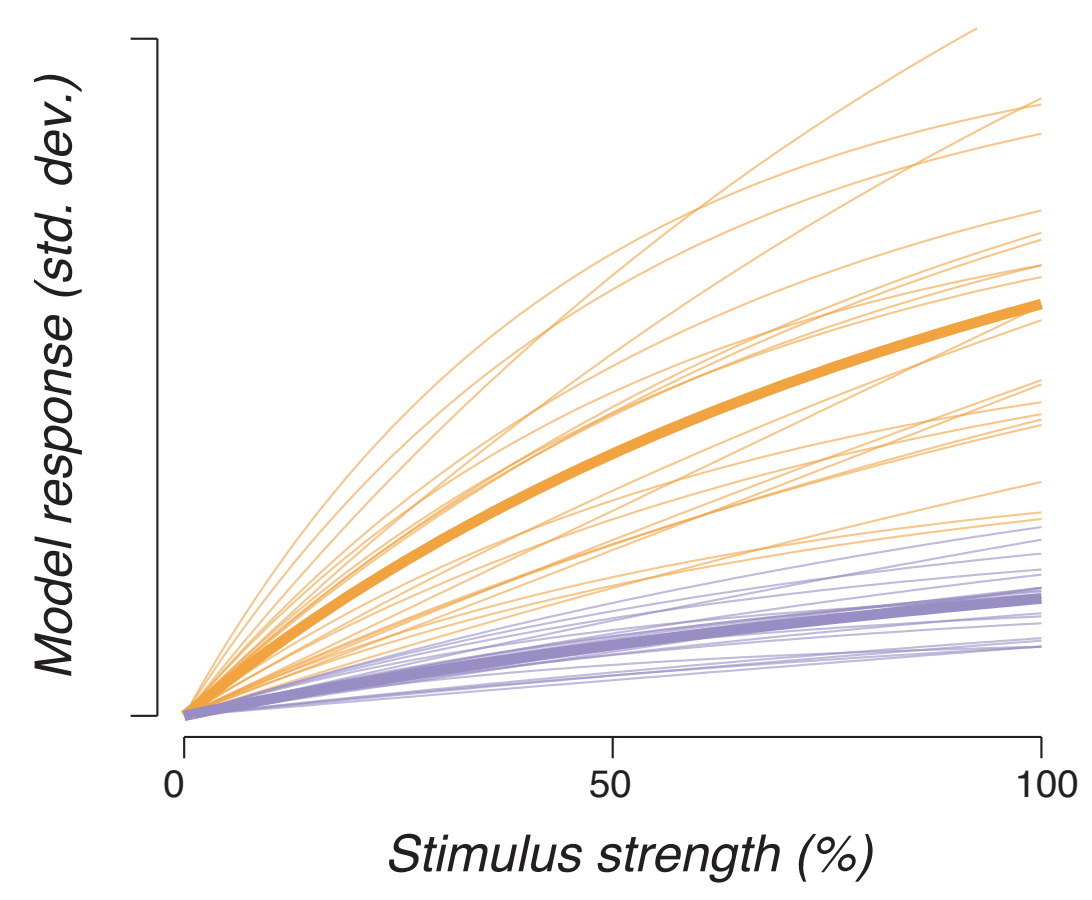
3. Discrimination task

We collected data on how well participants could discriminate small increments in contrast and motion coherence.
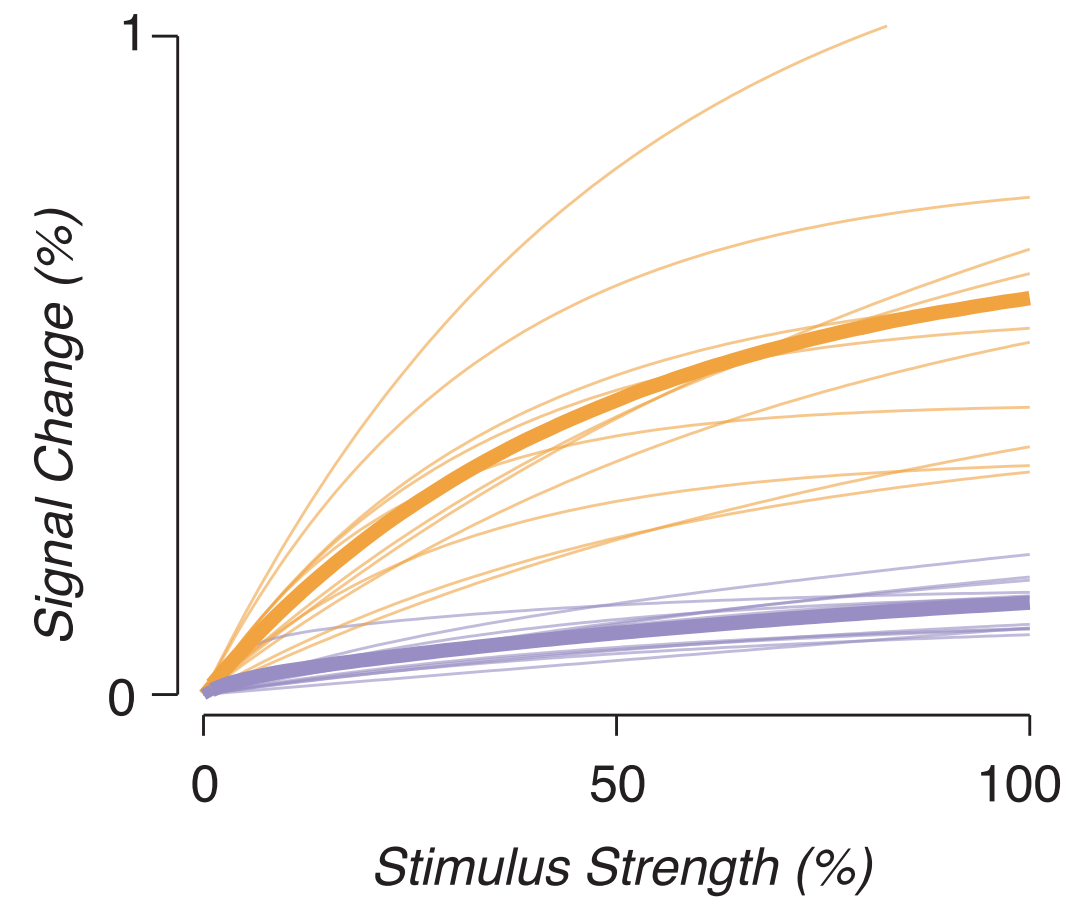
Contrast discrimination | Motion coherence discrimination

ITI: 200-400 ms
Stim: 500 ms
Delay: 500-1000 ms
Response: 1000 ms
Feedback

Left Right

Just noticeable differences (n=21)

Coherence
Contrast

Motion coherence JND slope: 0.329

Contrast JND slope: 0.056

2. Model: neural responses

Behavior: just noticeable differences

Signal detection / Weber-Fechner

+1 std. dev.
+1 std. dev.

Small JND   Large JND

fMRI: response timeseries

Constrain the shape/magnitude

Neural response functions

GLM (convolution)

Trial response + trial onset timeseries * Hemodynamic response function

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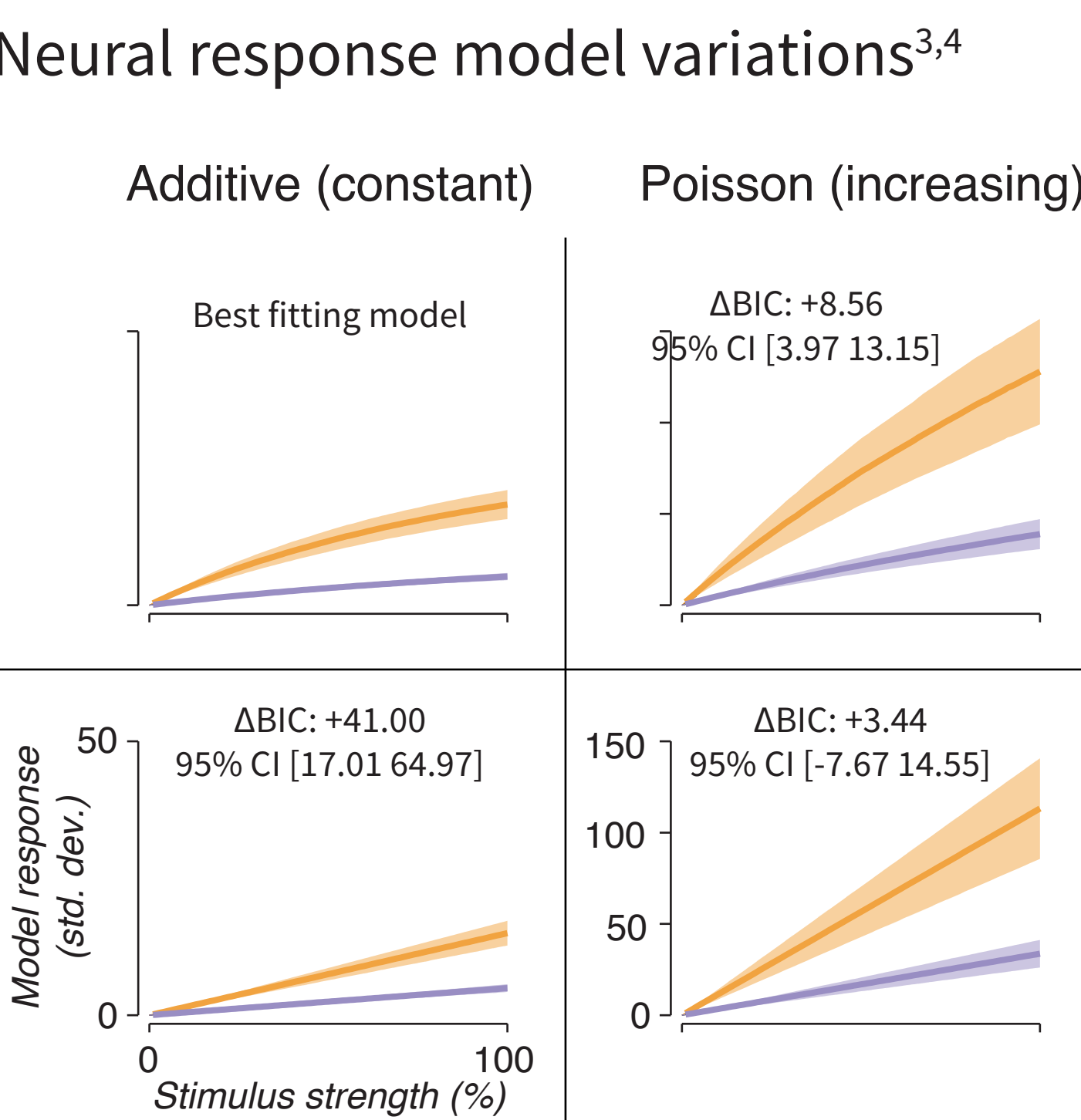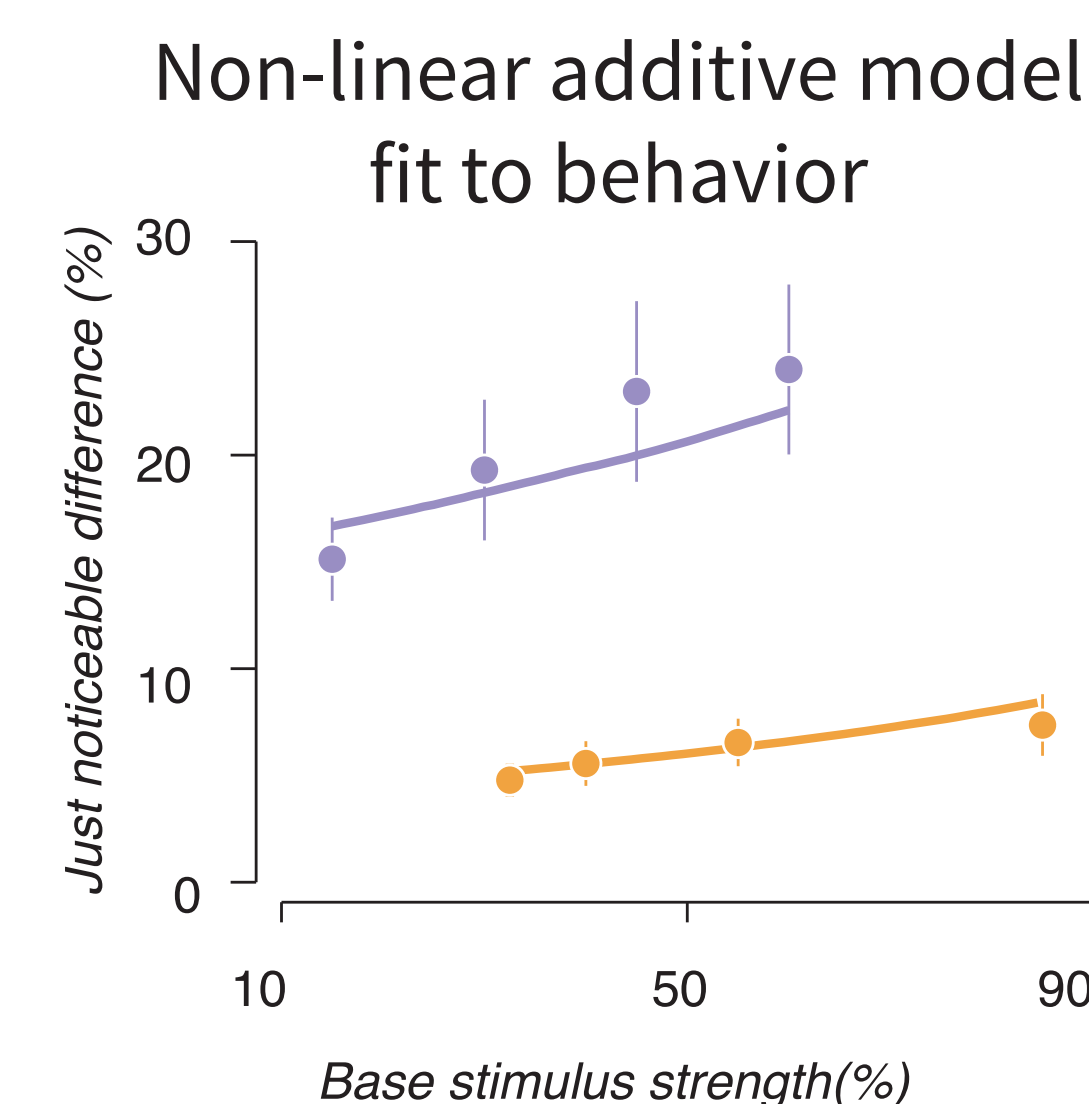
Contrast and motion coherence response functions constrained by behavior (n=21)

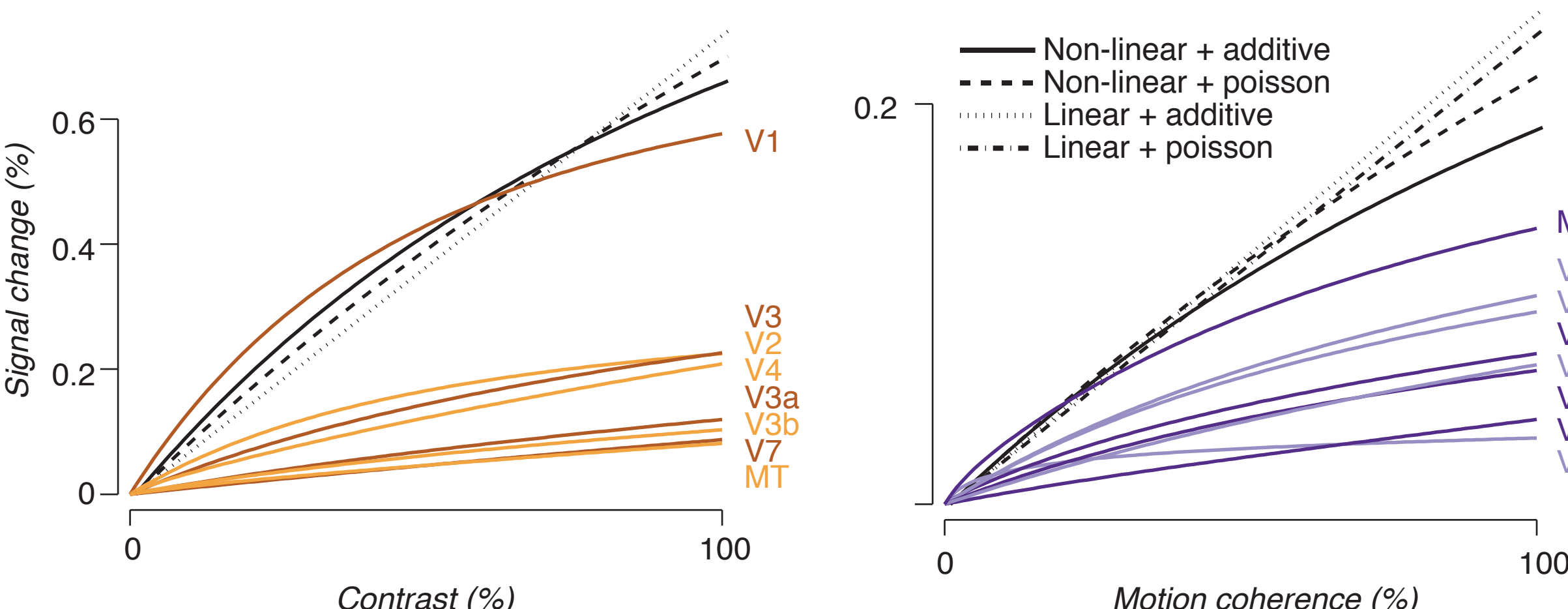V1 contrast and MT motion coherence response functions constrained by fMRI (n=11)

4. Cortical measurements (fMRI)

Cortical responses were measured during discrimination and passive observation while performing a fixation task.

Passive observation
ITI: 2-11 s
Stim: 0.25-4 s

V1

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

V1 contrast response

MT motion coherence response
Coherence+100%
Coherence+75%
Coherence+50%
Coherence+25%

V1 motion coherence response

MT

MT Contrast/Coherence Averages
Change in Motion Coherence (%)
+0 +25 +50 +75 +100

V1 Contrast/Coherence Averages
Change in Contrast (%)
+0 +25 +50 +75 +100

MT Timing Averages
Stimulus Length (ms)
250 500 1000 2000 4000

V1 Timing Averages
250 500 1000 2000 4000

5. Response functions

Non-linear additive model fit to behavior

Neural response model variations[3,4]

Additive (constant) | Poisson (increasing)

Non-linear

Best fitting model

ΔBIC: +8.56
95% CI [3.97 13.15]

Linear

ΔBIC: +41.00
95% CI [17.01 64.97]
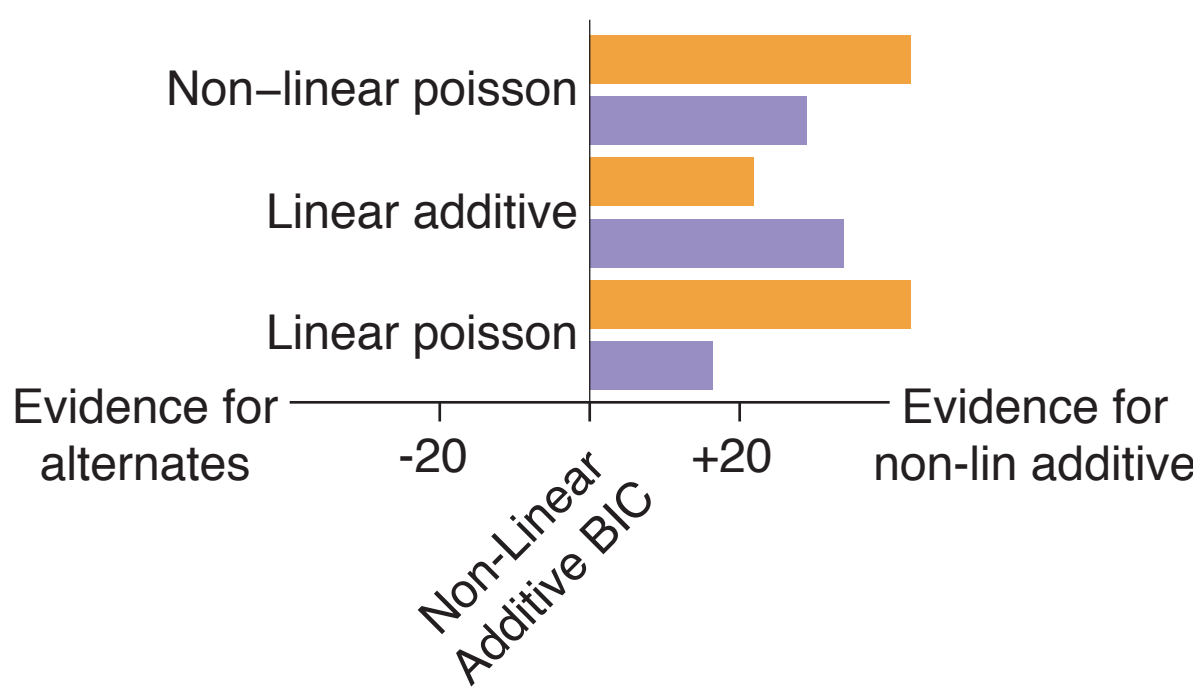
ΔBIC: +3.44
95% CI [-7.67 14.55]

6. Behavior to fMRI

We fit a neural noise[5] parameter to scale response models into the same space. Based on previous work[1] we fit this parameter using the functions constrained on V1 and contrast discrimination.
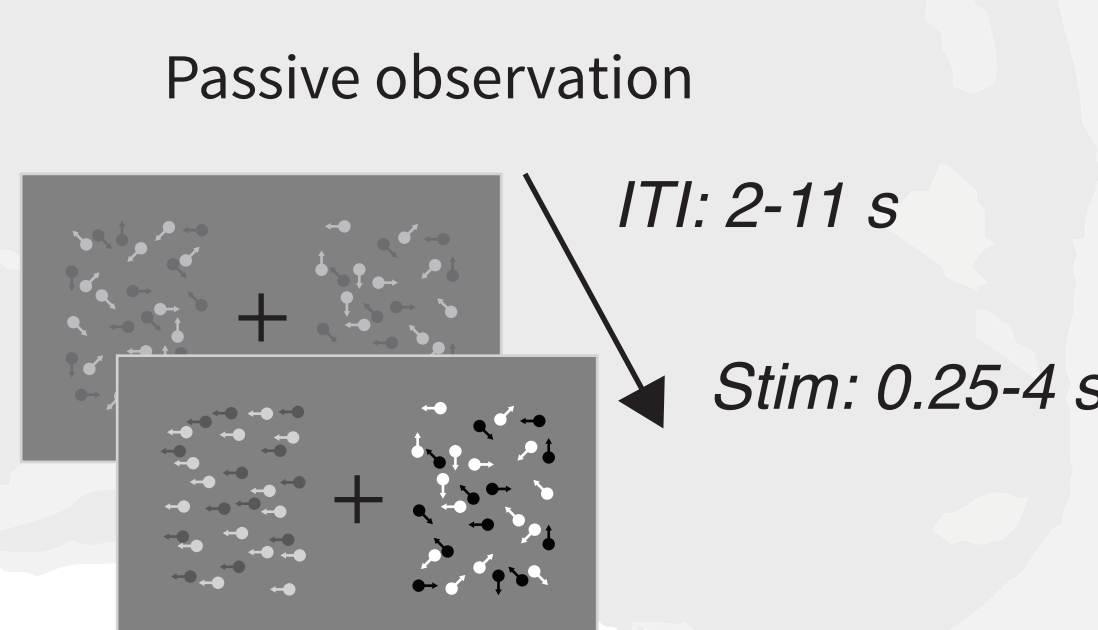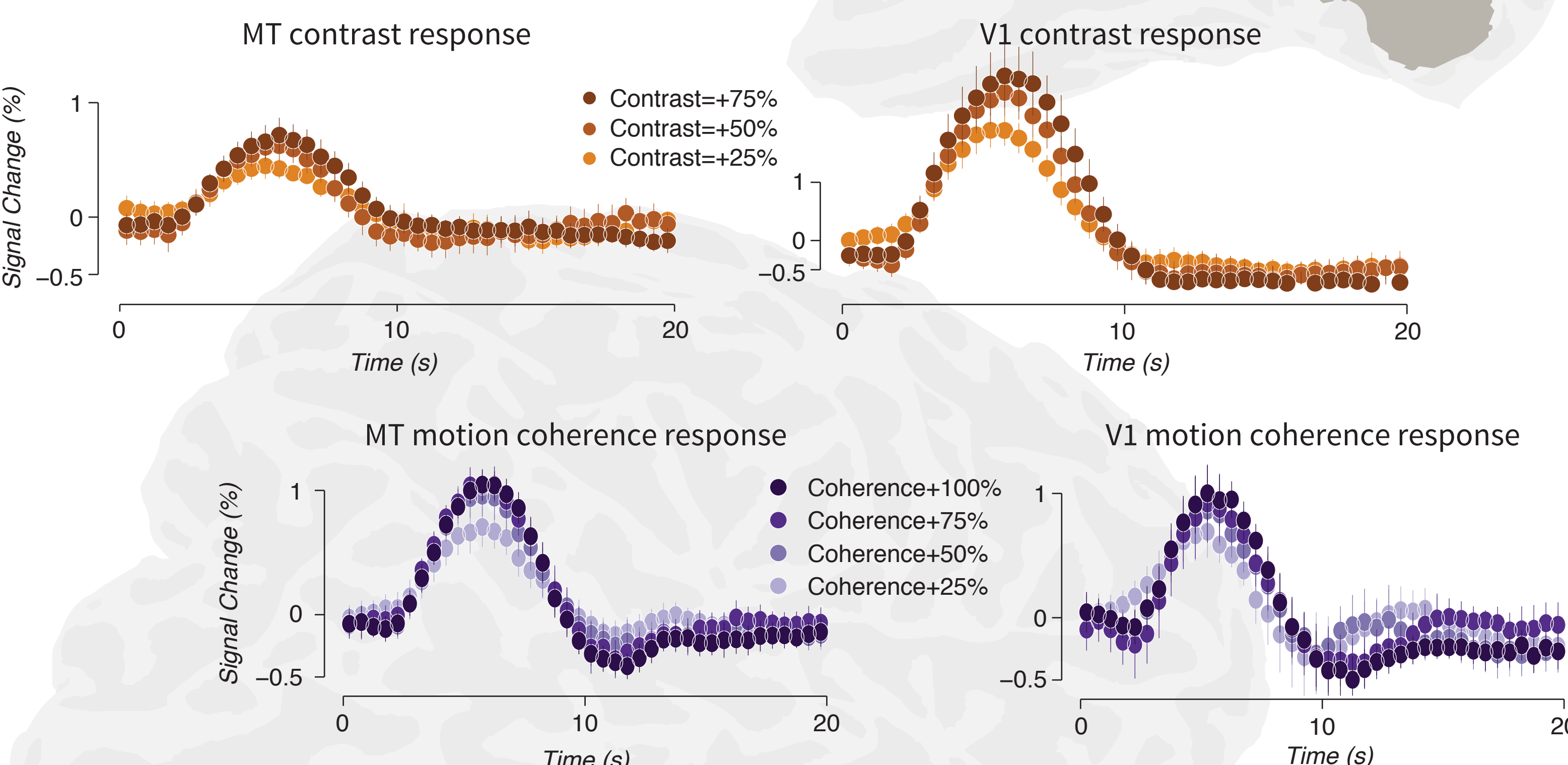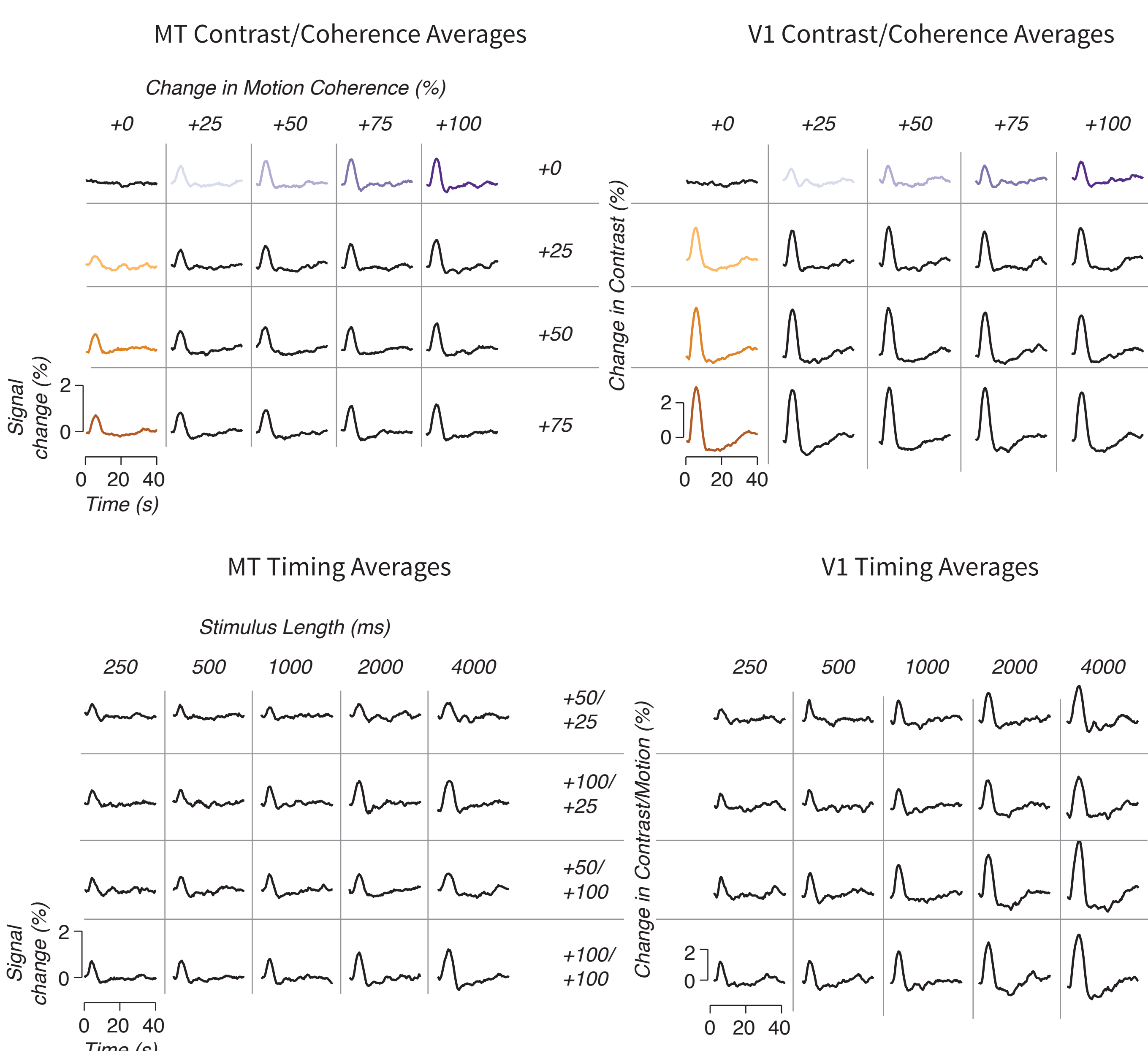
Non-linear + additive
Non-linear + poisson
Linear + additive
Linear + poisson

V1
V3
V2
V4
V3a
V3b
V7
MT

MT
V3a
V3
V2
V7
V3b
V4
V1

Model comparison of behavioral contrast and motion coherence response models to V1 and MT, respectively

Non-linear poisson
Linear additive
Linear poisson

Evidence for alternates   Evidence for non-lin additive

Non-Linear Additive BIC

1. Boynton, G. M., Demb, J. B., Glover, G. H., & Heeger, D. J. Vision Research (1999).
3. V5/MT is thought to respond linearly to increasing motion coherence (see also 4). Rees, G., Friston, K., & Koch, C. Nature neuroscience (2000).
4. Simoncelli, E. P., & Heeger, D. J. Vision Research (1998).
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. Neuron (2011).

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