Flexible readout of stable cortical representations support motion visibility perception

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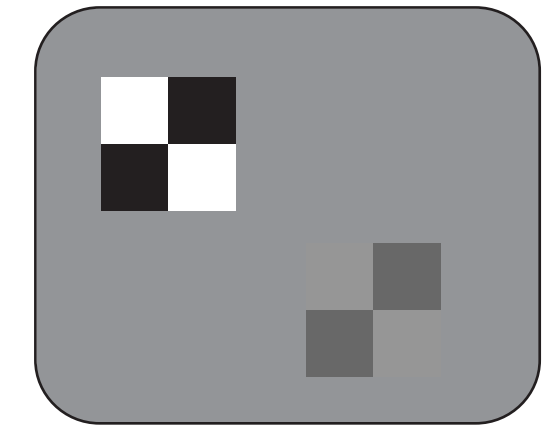
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1. Introduction

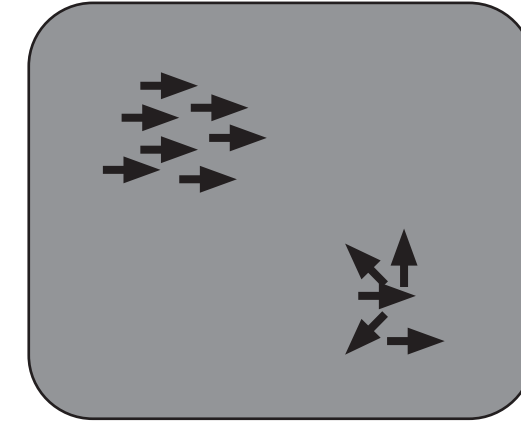Perceptual sensitivity to specific features improves[1] when observers are told which of two features is relevant:

Contrast
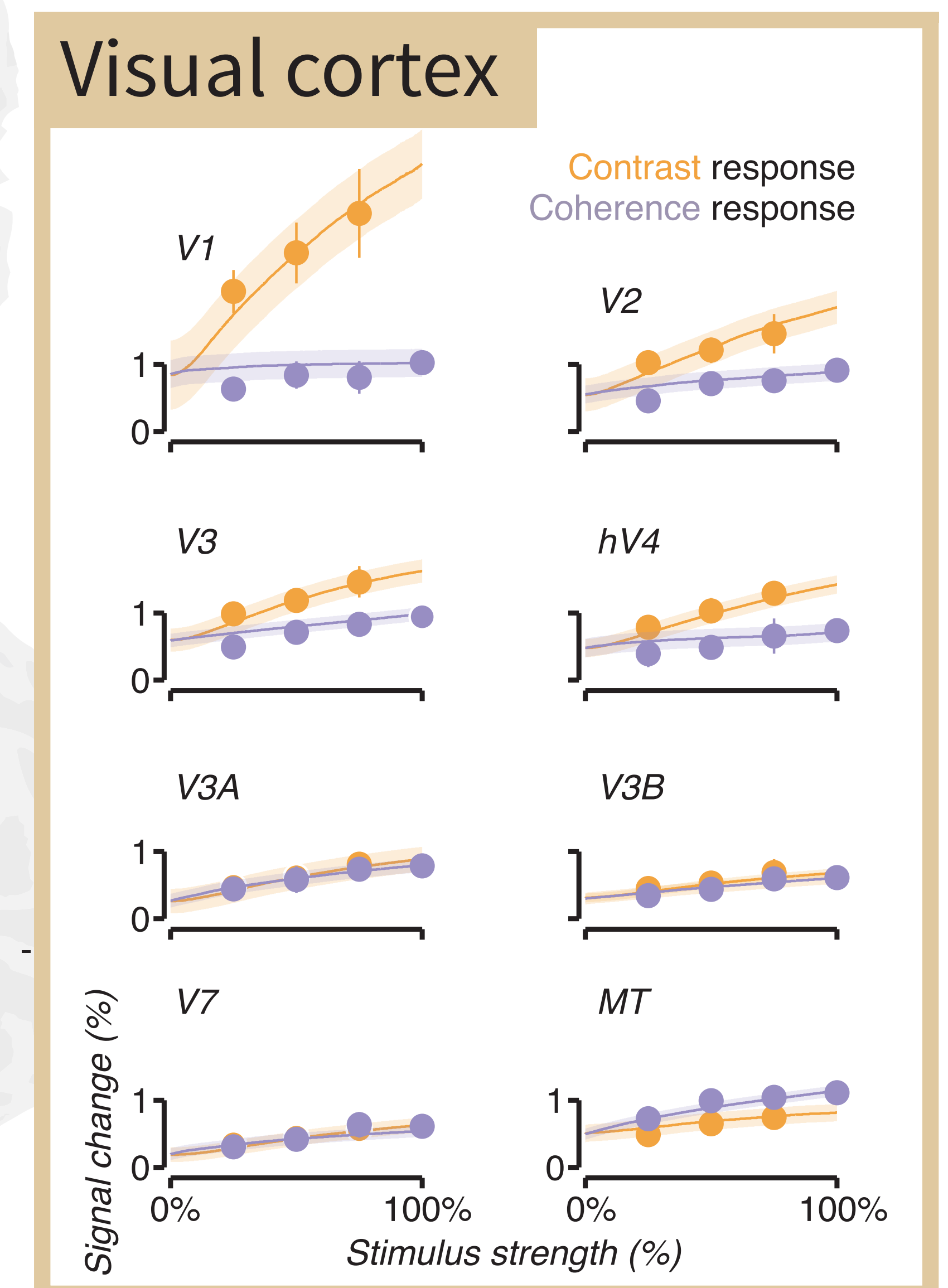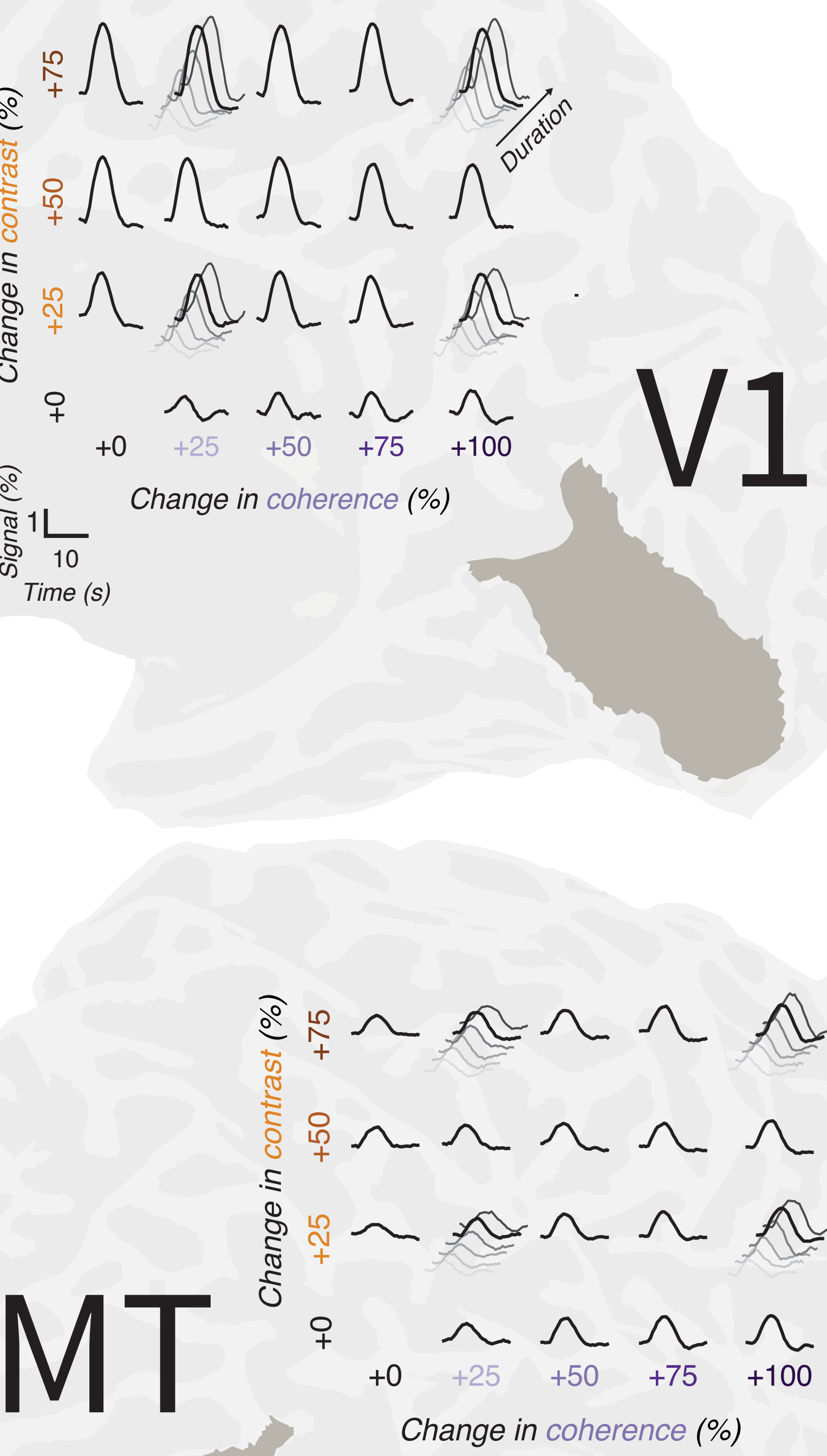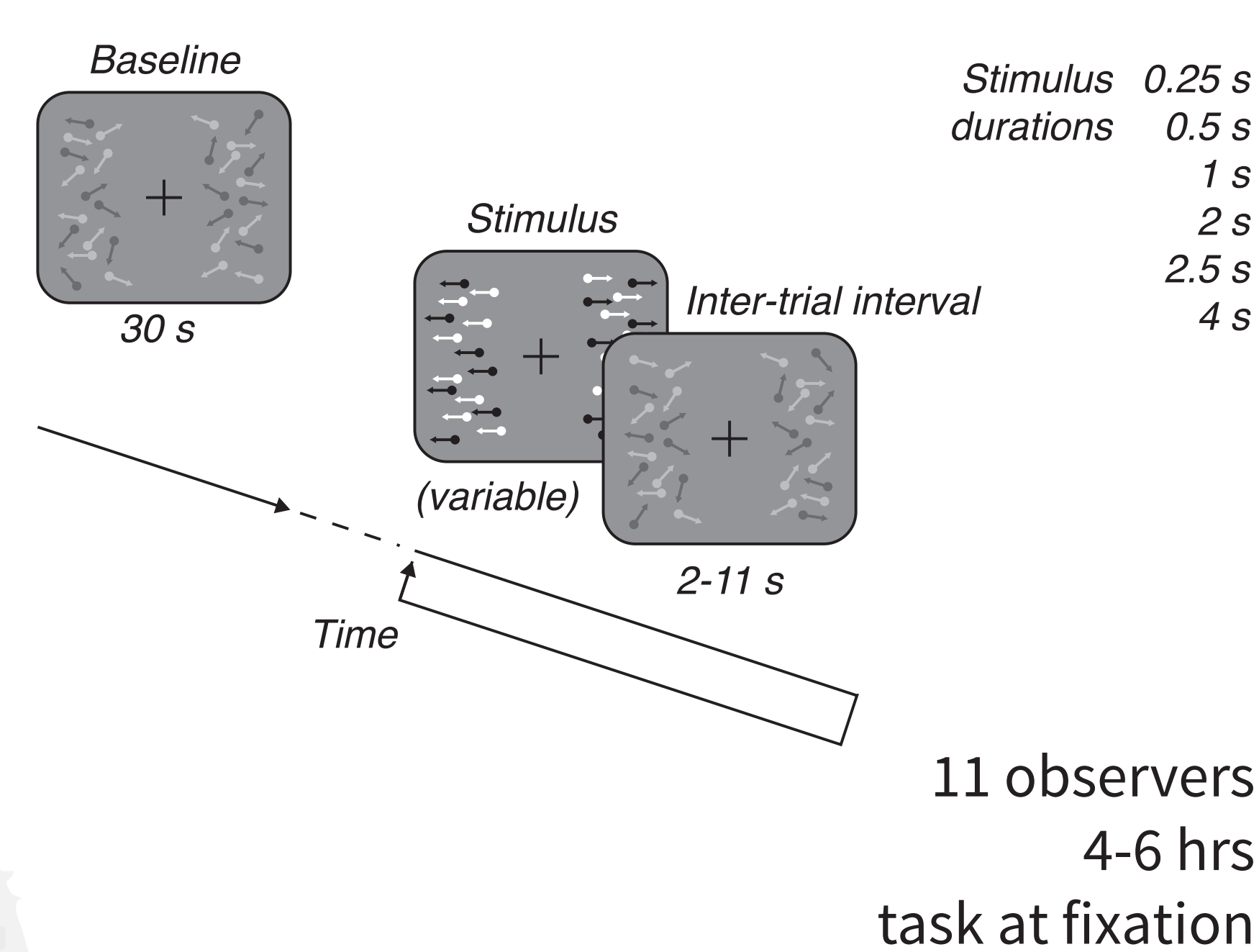The relative luminance to a gray background

Coherence
The proportion of dots moving in the same direction

These behavioral changes could be implemented by changes in sensory representation or readout. We study this by building linking models connecting physiology to perception.
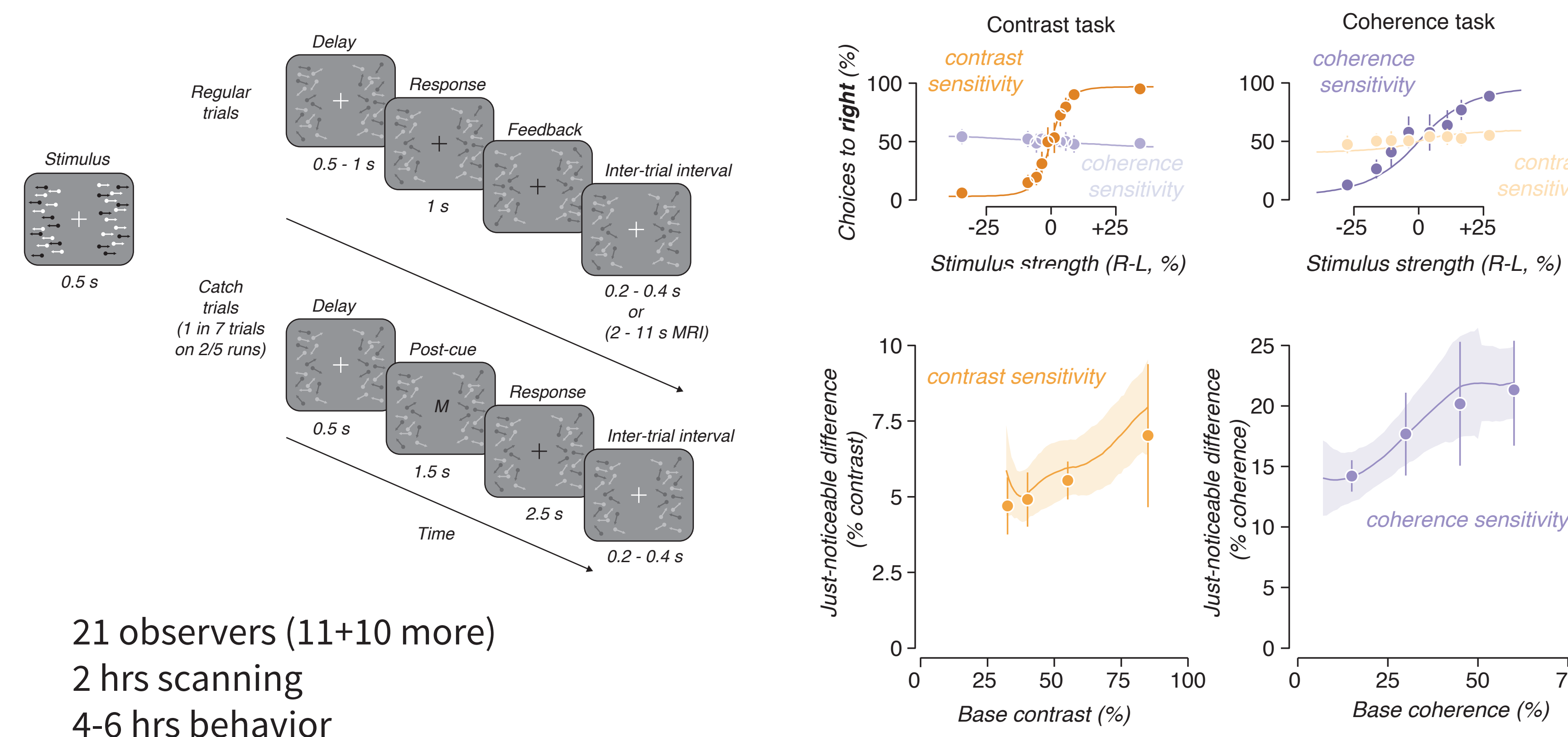
2. BOLD signal measurements

We studied contrast and coherence, two features that independently control motion visibility. Both are represented by monotonic increasing response in visual cortex, in overlapping regions[2].

Baseline 30 s
Stimulus
Inter-trial interval
(variable)
2-11 s
Time

Stimulus durations	
	0.25 s
	0.5 s
	1 s
	2 s
	2.5 s
	4 s

11 observers
4-6 hrs
task at fixation

Visual cortex

Contrast response
Coherence response

V1, V2, V3, hV4, V3A, V3B, V7, MT

## 3. Context-dependent perceptual sensitivity

We measured how well participants could discriminate small increments in contrast and motion coherence. Observers were able to discriminate each feature independently of the other.

Regular trials — Stimulus 0.5 s, Delay 0.5 - 1 s, Response, Feedback 1 s, Inter-trial interval 0.2 - 0.4 s or (2 - 11 s MRI)

Catch trials (1 in 7 trials on 2/5 runs) — Stimulus 0.5 s, Delay, Post-cue 1.5 s, Response 2.5 s, Inter-trial interval 0.2 - 0.4 s

Time

Contrast task — contrast sensitivity, coherence sensitivity
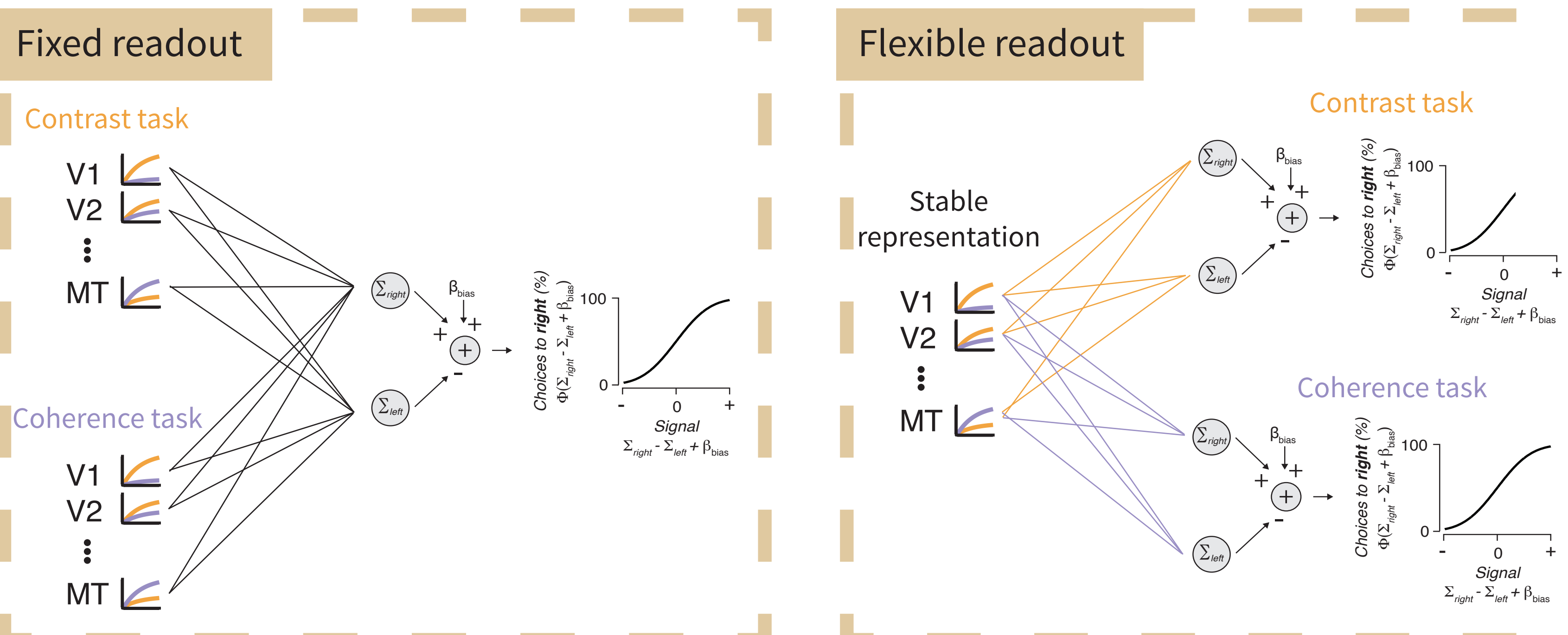Coherence task — coherence sensitivity, contrast sensitivity

21 observers (11+10 more)
2 hrs scanning
4-6 hrs behavior

4. Linking model

To build a computational description of the steps that lead from sensory representation to perceptual decisions we extended a model of contrast discrimination[3] to two features by allowing different cortical areas to be weighted in a context-dependent manner.
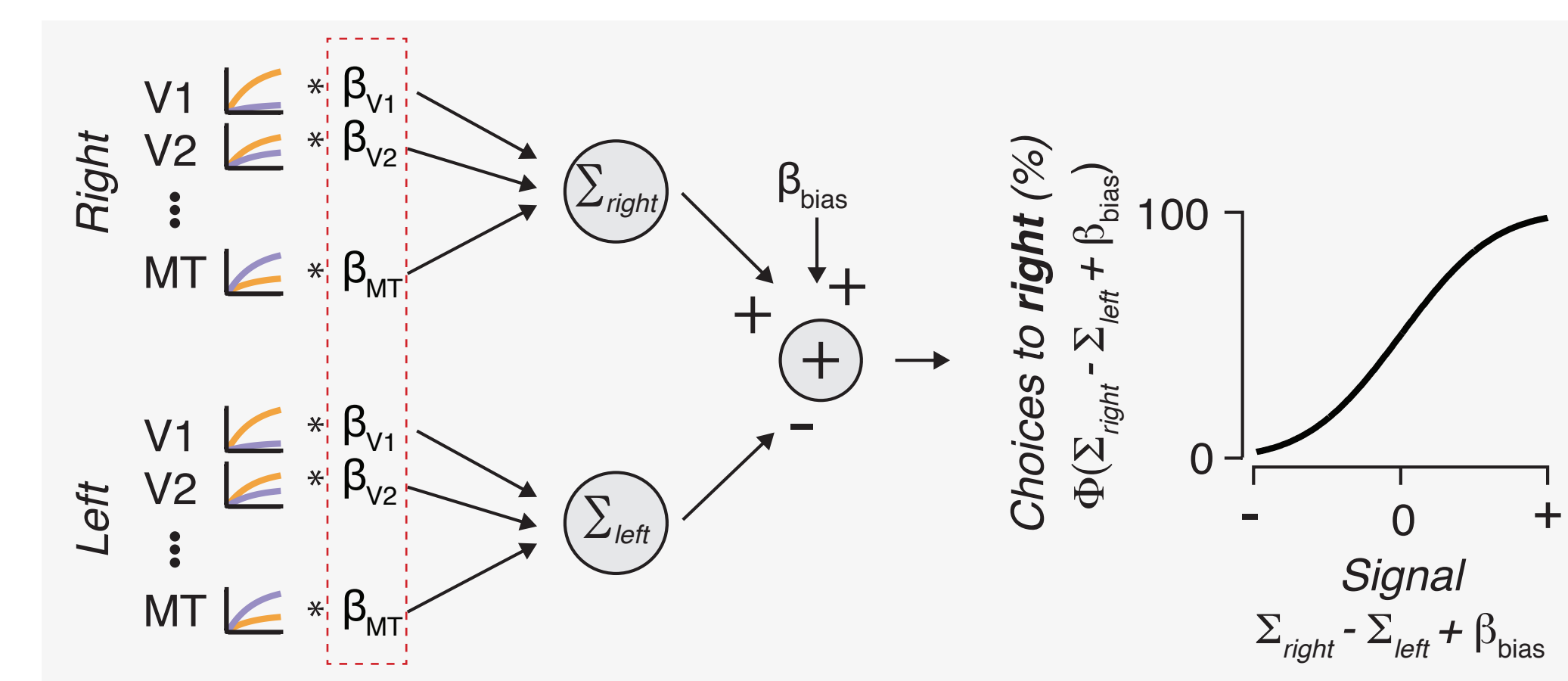

The actual implementation of weights could occur in sensory areas, or downstream:

Fixed readout
Contrast task
Coherence task

Flexible readout
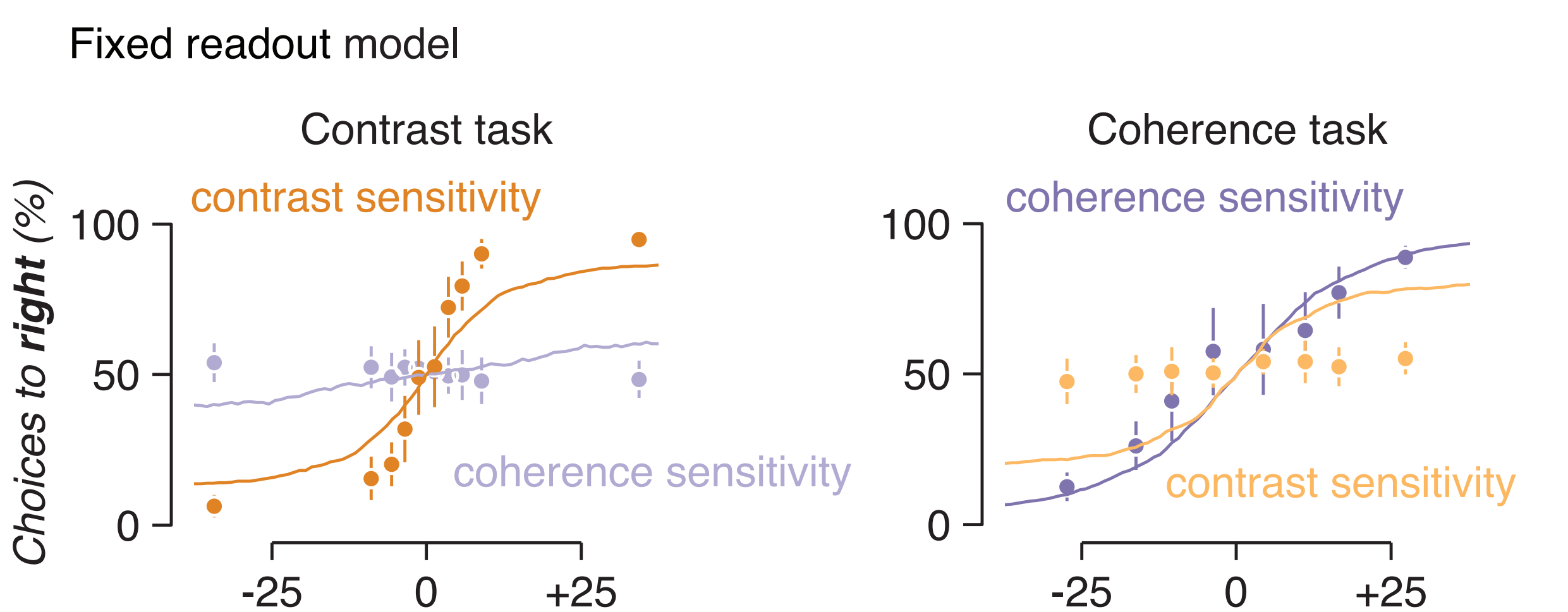Stable representation
Contrast task
Coherence task

5. Fixed readout?

The linking model predicts that if the weights are implemented by sensory change then as context shifts we should see large changes in sensitivity.

When observers performed each task we only measured small changes in sensitivity, and no difference in other measures (e.g. shifts in baseline).


contrast task
coherence task
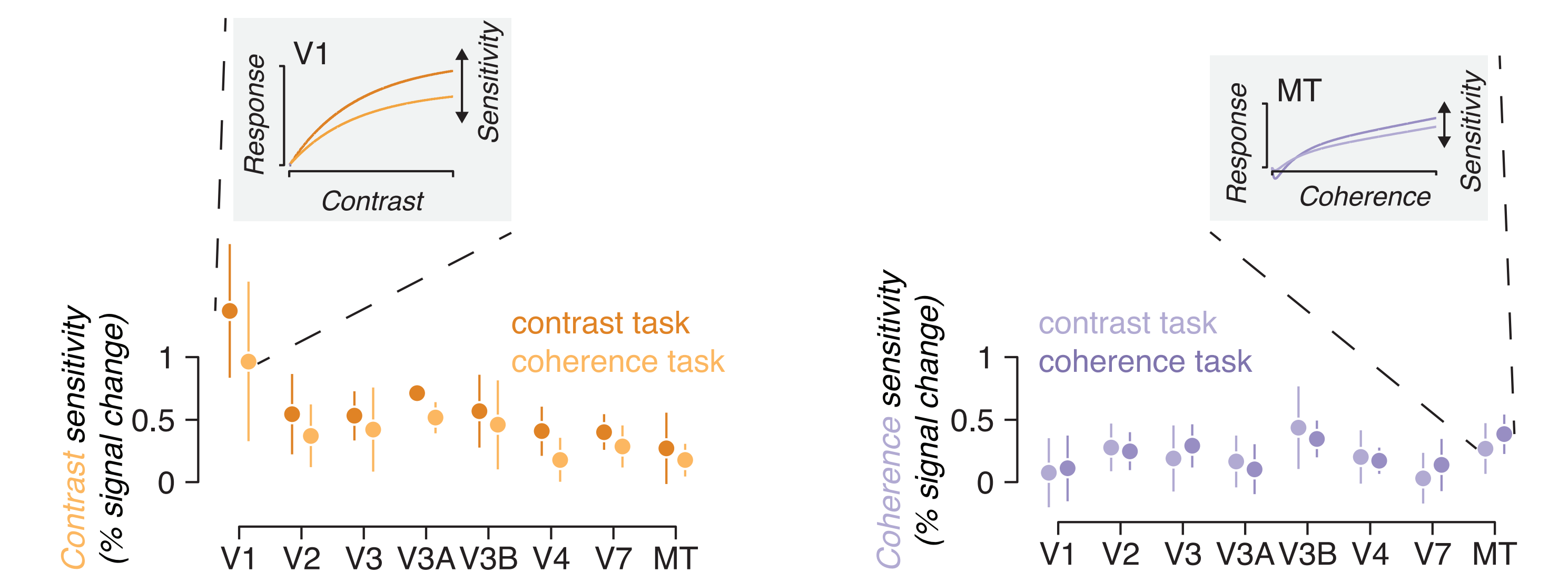
Using the sensitivity in each context we formally tested the fixed readout and flexible readout models and found that only the flexible readout model could fit the data.

Fixed readout model

Contrast task — contrast sensitivity, coherence sensitivity
Coherence task — coherence sensitivity, contrast sensitivity

6. Flexible readout.

In an uncertain world keeping sensory representations stable is a benefit! On unexpected "catch" trials observers changed their mind after preparing to respond[4]. They were able to do this with less loss in sensitivity than a fixed model predicted.

Predicted just-noticeable difference
- - - Fixed readout
— Flexible readout with noise

Catch / Control
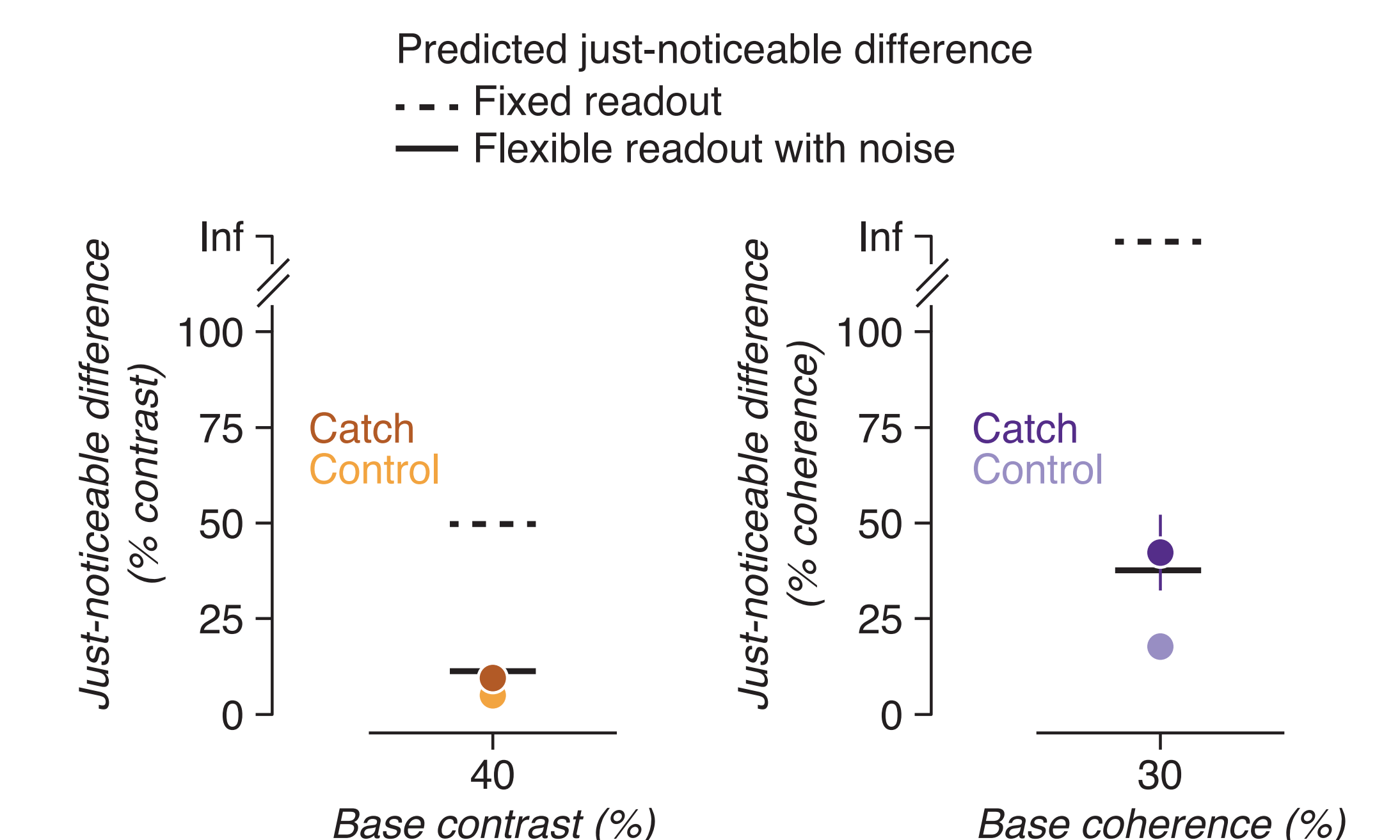
All data show bootstrapped mean and 95% confidence interval across subjects.
Contrast response function:
$$R(contrast) = \alpha \frac{contrast^{1.9}}{contrast^{1.6} + \sigma^{1.6}}$$
Coherence response function:
$$R(coherence) = \alpha(1 - e^{\frac{coherence}{\kappa}})$$

1. Carrasco, M. (2011). Visual attention: The past 25 years. *Vision research*, 51(13), 1484-1525.
2. Birman, D., & Gardner, J. L. (2018). A quantitative framework for motion visibility in human cortex. *Journal of neurophysiology*, 120(4), 1824-1839.
3. Boynton, G. M., Demb, J. B., Glover, G. H., & Heeger, D. J. *Vision Research* (1999).
4. Mack, A., & Rock, I. (1998). Inattentional blindness (Vol. 33). Cambridge, MA: MIT press.

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