Flexible readout of stable cortical representations support motion visibility perception

Daniel Birman, Justin L. Gardner

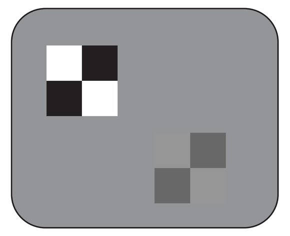
Department of Psychology, Stanford University
danbirman@stanford.edu

1. Introduction

Sensitivity to specific features improves[1] when observers are told which of two features is relevant, e.g. motion visibility:

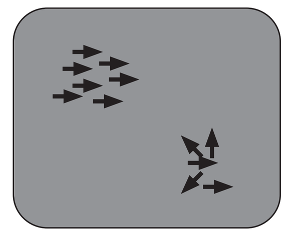
Contrast

The relative luminance to a gray background



Coherence

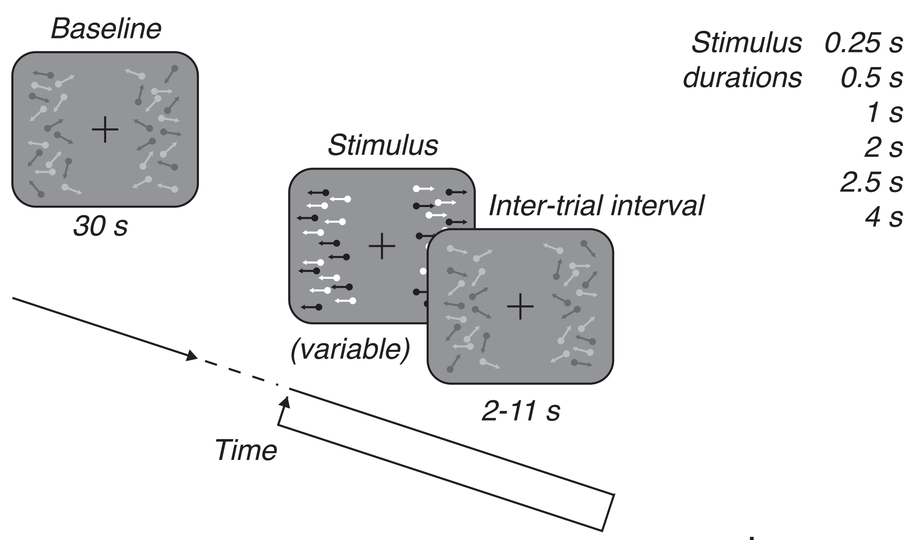
The proportion of dots moving in the same direction



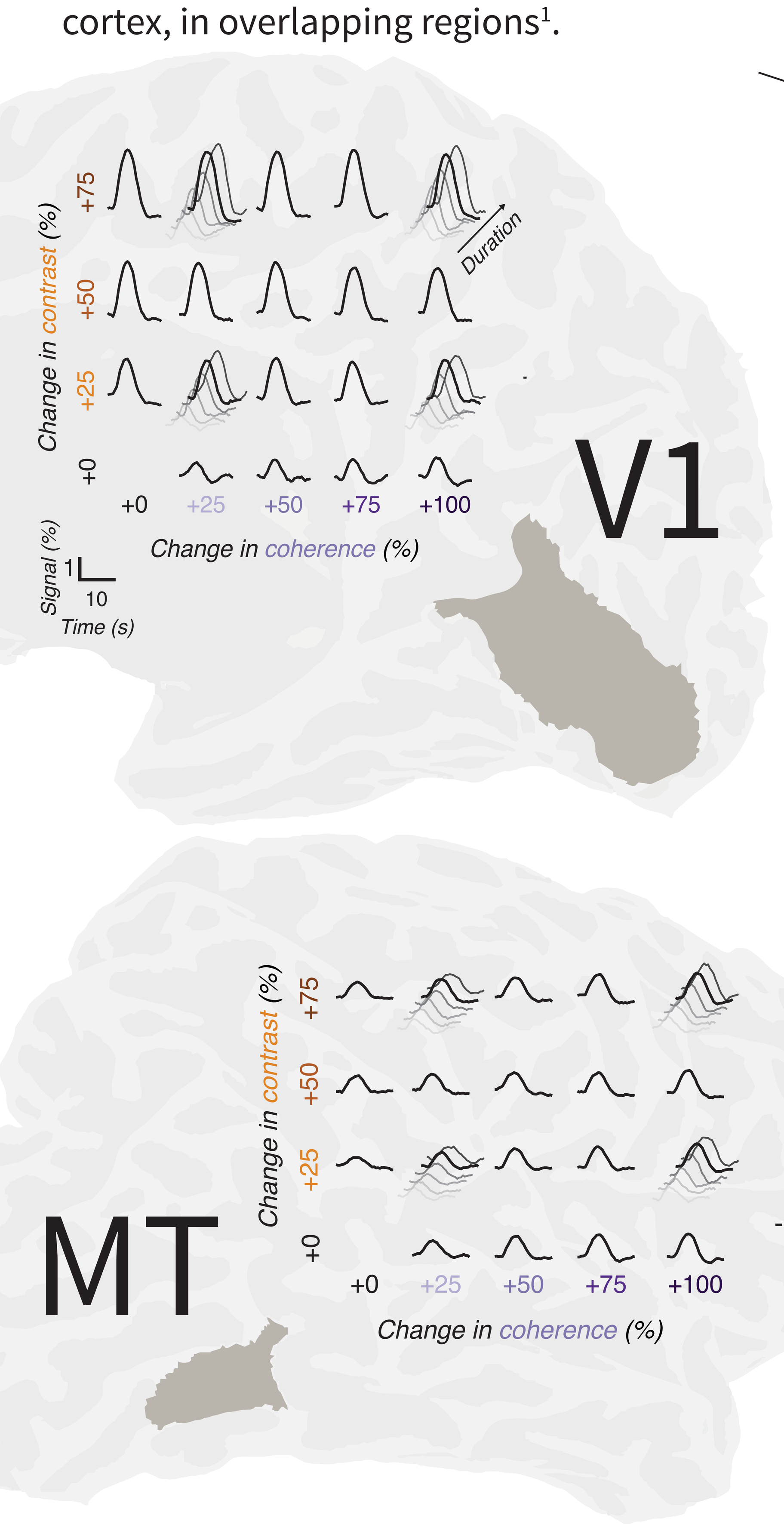
These behavioral changes could be implemented by changes in sensory representation or readout. To study this we need to build linking models connecting physiology to perception.

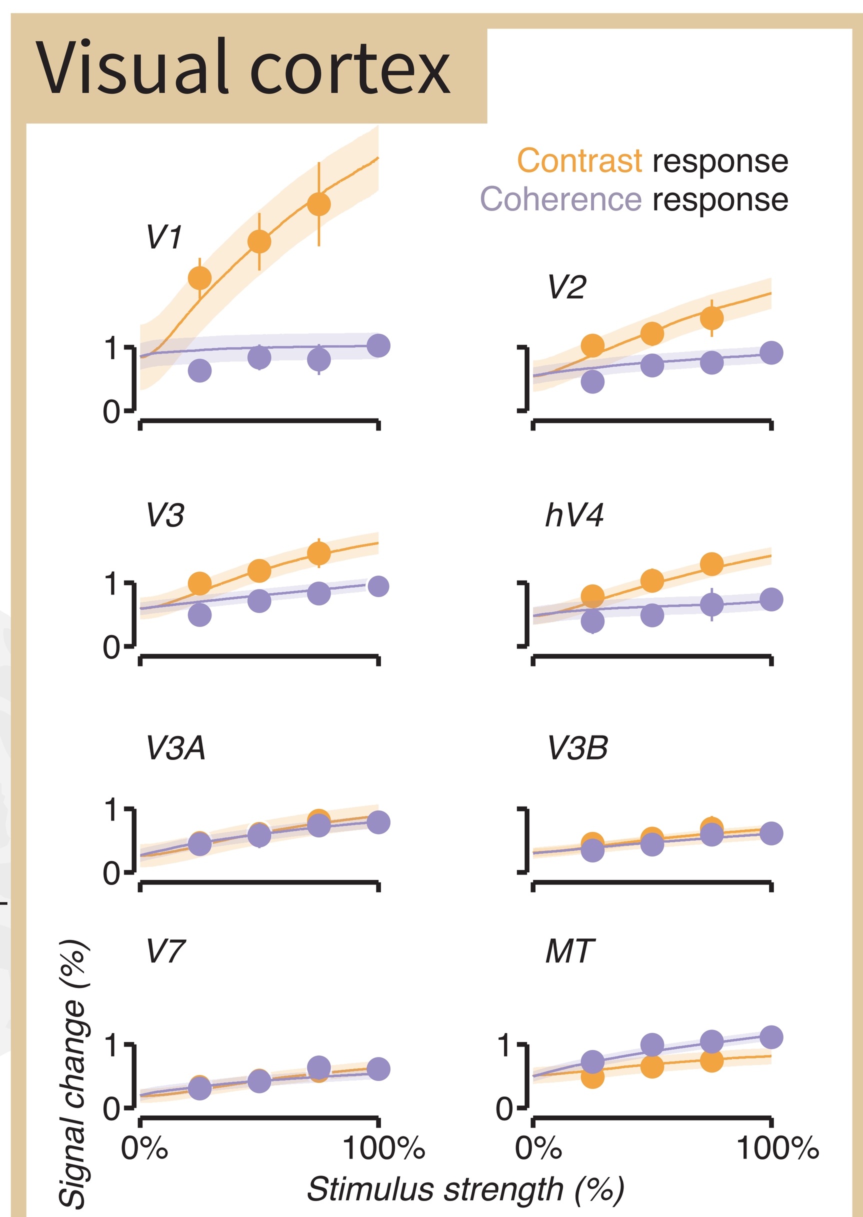
2. BOLD signal measurements[2]

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[1].



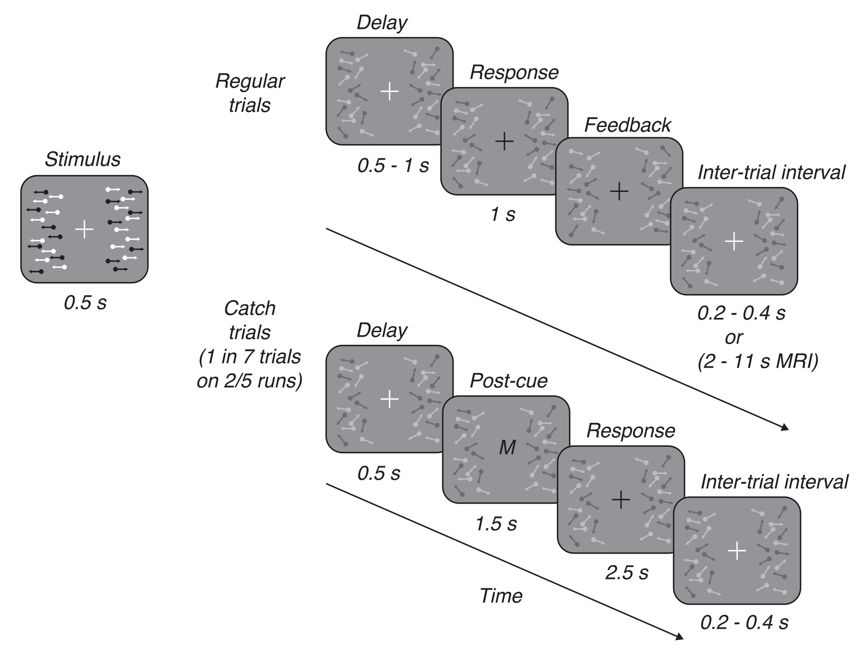
11 observers
4-6 hrs
task at fixation

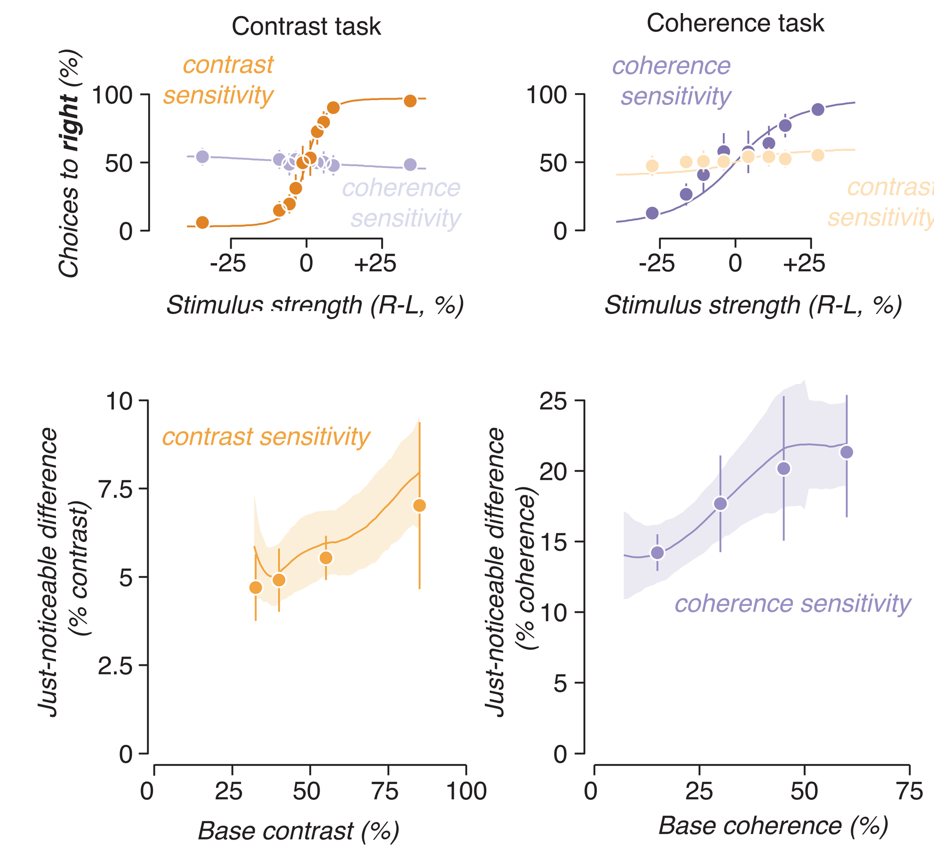




3. Context-dependent perceptual sensitivity

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.

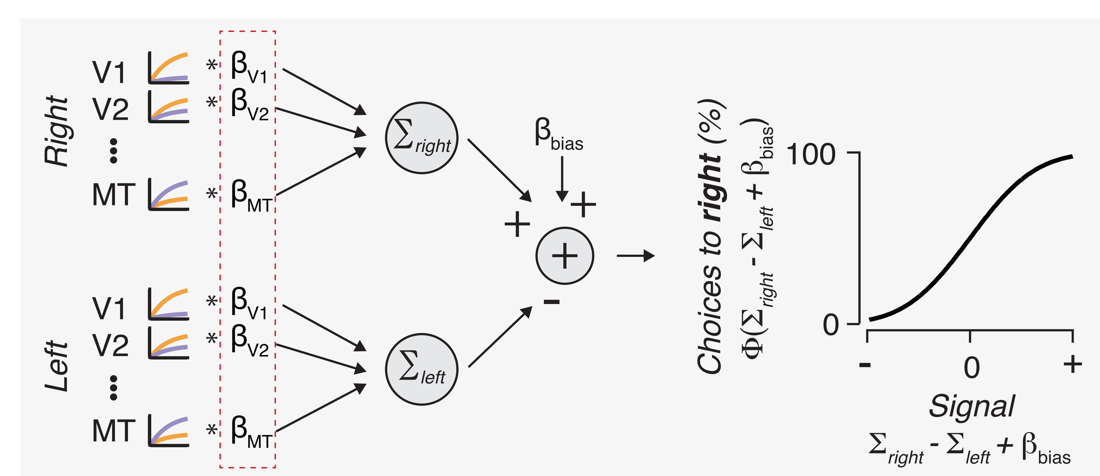




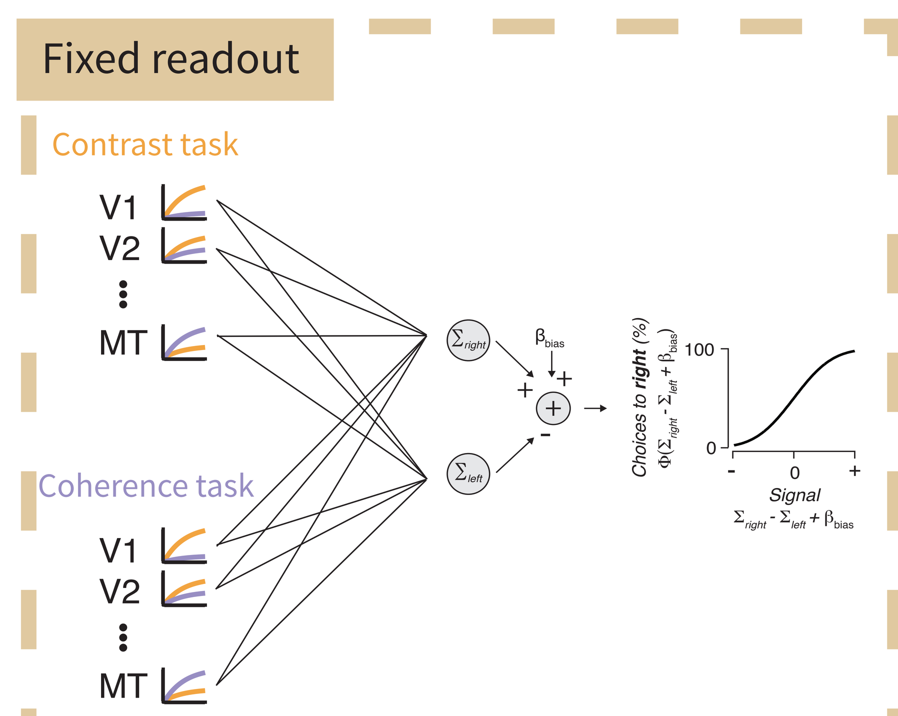
21 observers (11+10 more)
2 hrs scanning
4-6 hrs behavior

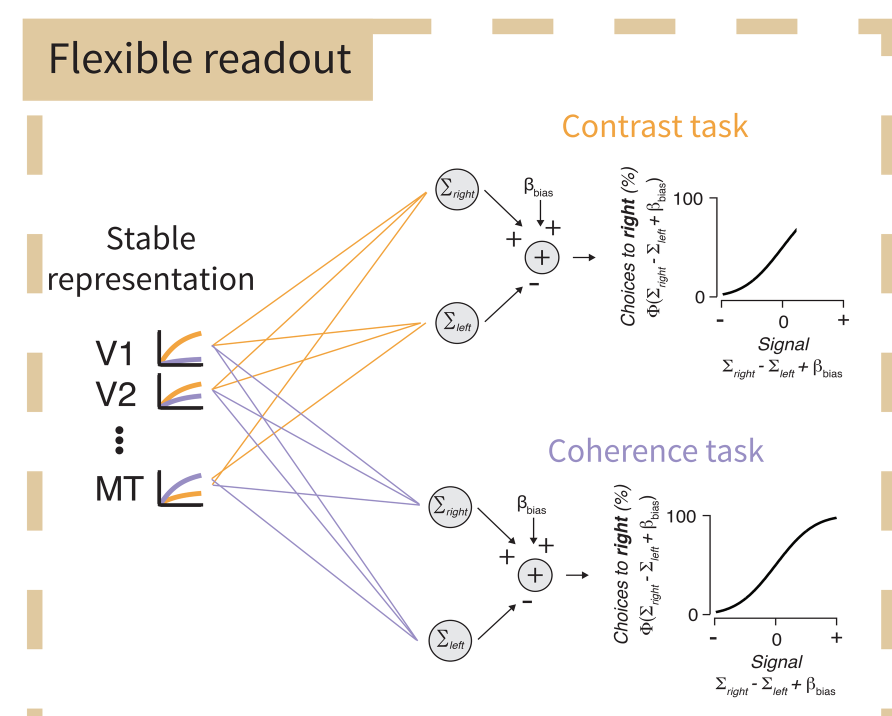
4. Linking model

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. We allowed different cortical area's responses to be weighted in a context-dependent manner.



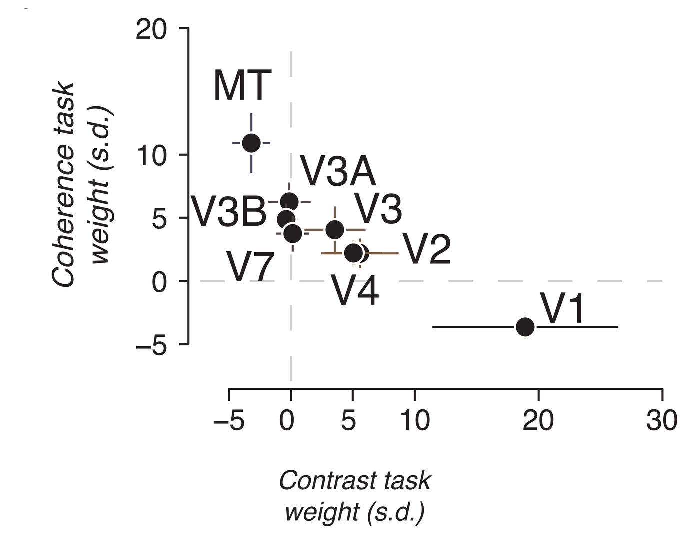
The actual implementation of weights could occur in sensory areas, or downstream:



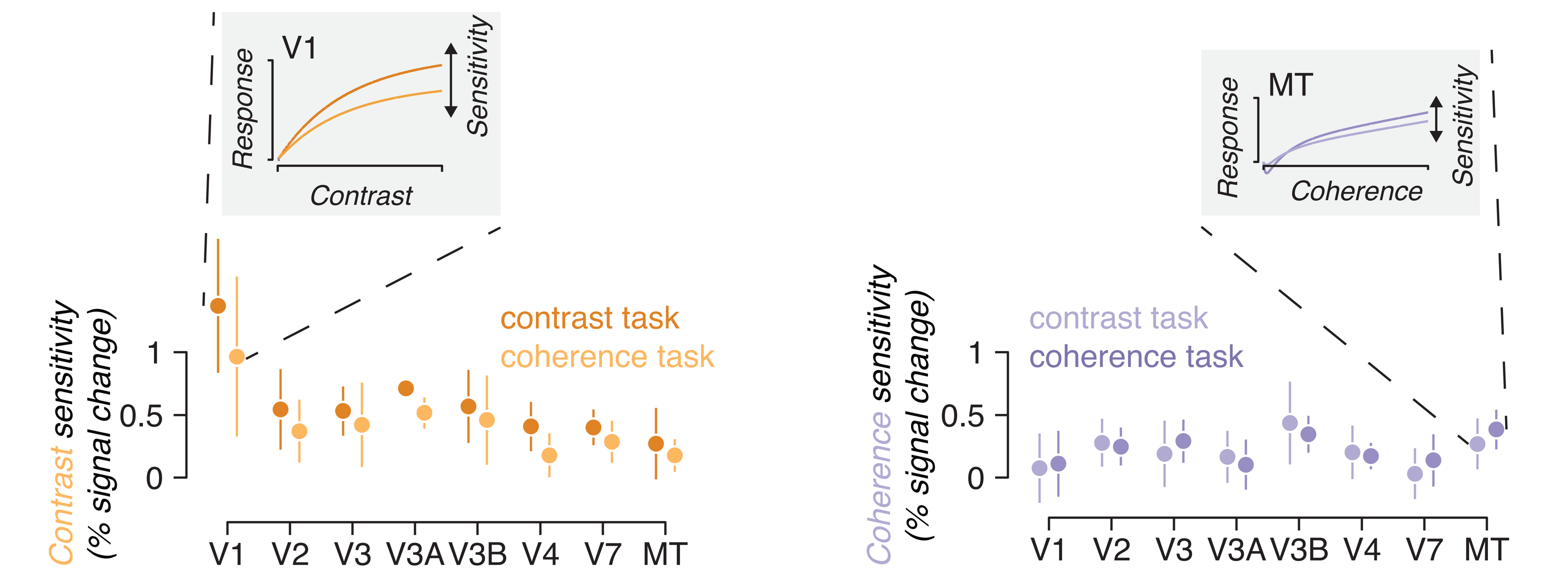


5. Fixed readout?

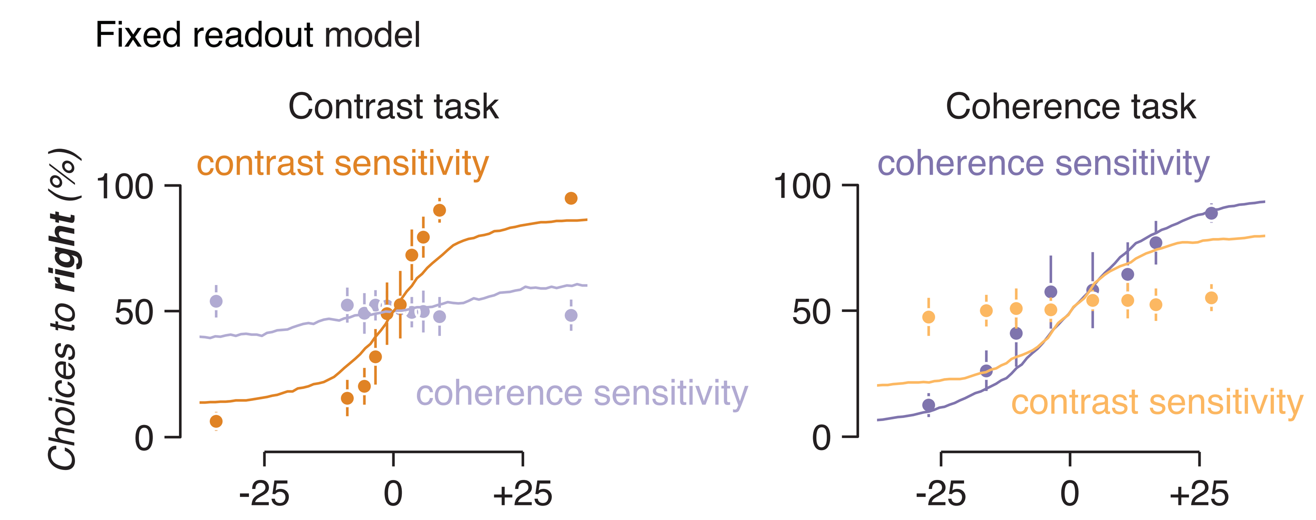
The linking model predicts that if the weights are implemented by sensory change then as context shifts we should see large changes in sensitivity.



When observers performed each task we only measured small changes in sensitivty:

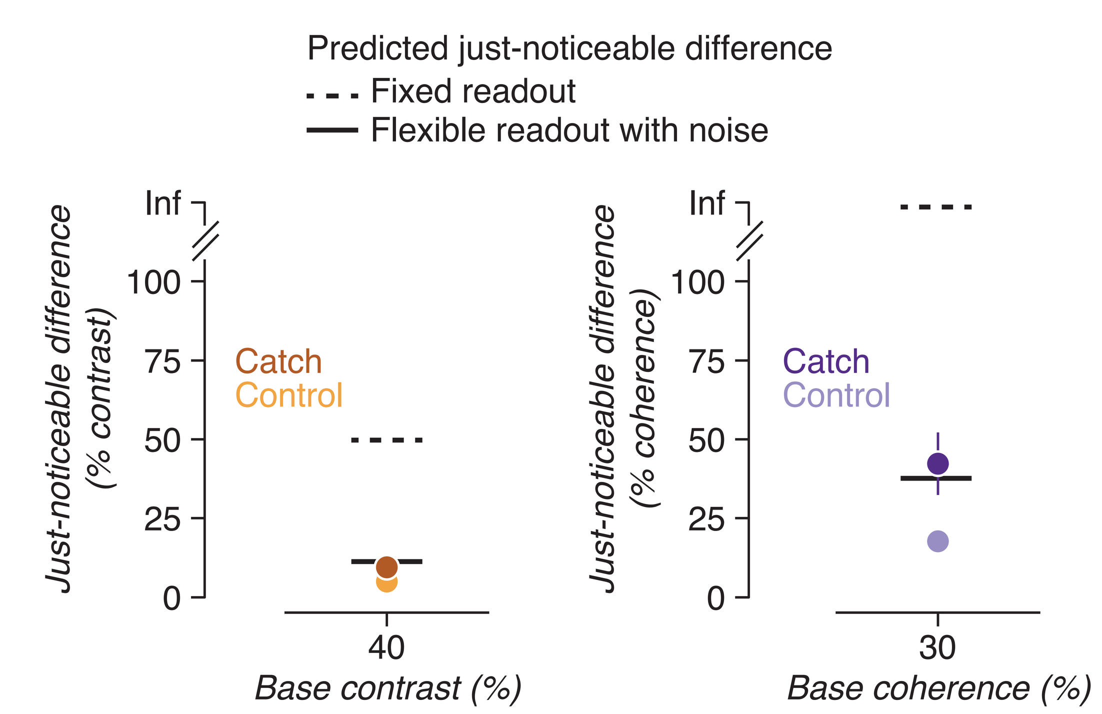


Using the sensitivity in each context we formally tested the fixed readout and flexible readout models and found that only the flexible readout model could fit the data.



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.



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:

$$R(coherence) = \alpha \left(1 - e^{-\frac{coherence}{\kappa}}\right)$$

1. Treue, S., & Trujillo, J. C. M. (1999). Feature-based attention influences motion processing gain in macaque visual cortex. *Nature*, 399(6736), 575.
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.

Stanford Psychology