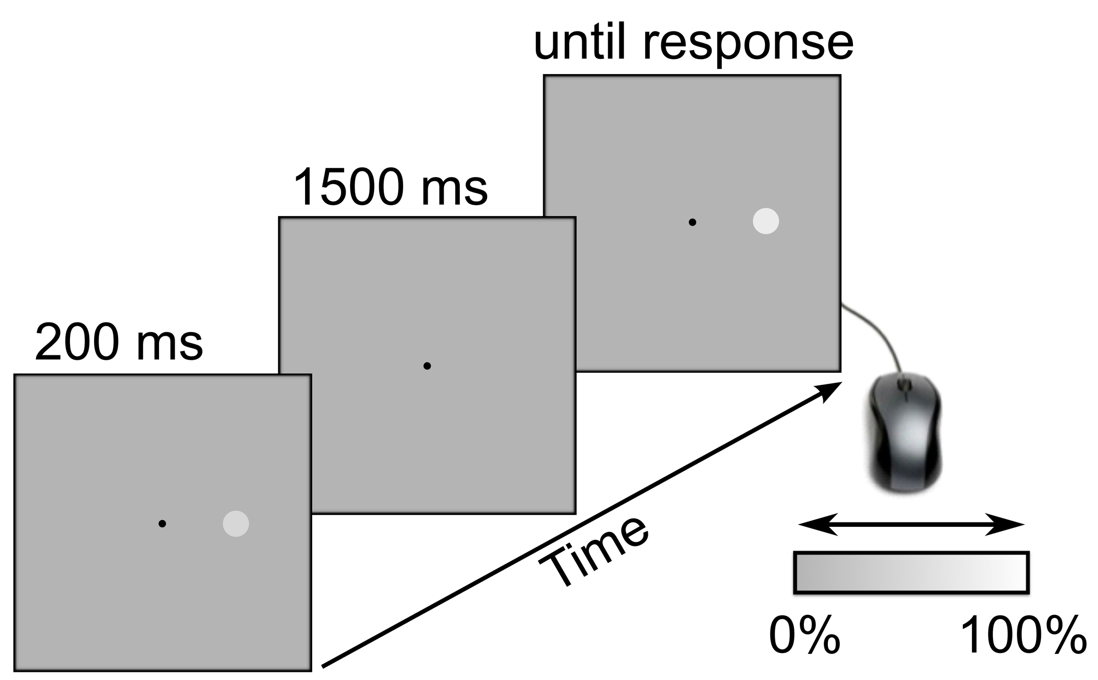
Memory precision in a contrast estimation task

Stuart Jackson[1], Wei Ji Ma[1,2]
[1]*Center for Neural Science, New York University,* [2]*Department of Psychology, New York University*

Goal

- Delayed-estimation tasks have elucidated the nature of visual short-term memory (VSTM), most notably for orientation and color [1].
- Such features are relatively stable in VSTM over time, presumably due to the topographic or pathway-specific nature of their encoding.
- For intensity-coded features such as luminance contrast, however, VSTM might be less stable over time; yet, data relevant to this question come from only coarse 2-AFC tasks [2].
- Here, we systematically investigated VSTM for luminance contrast using delayed estimation.

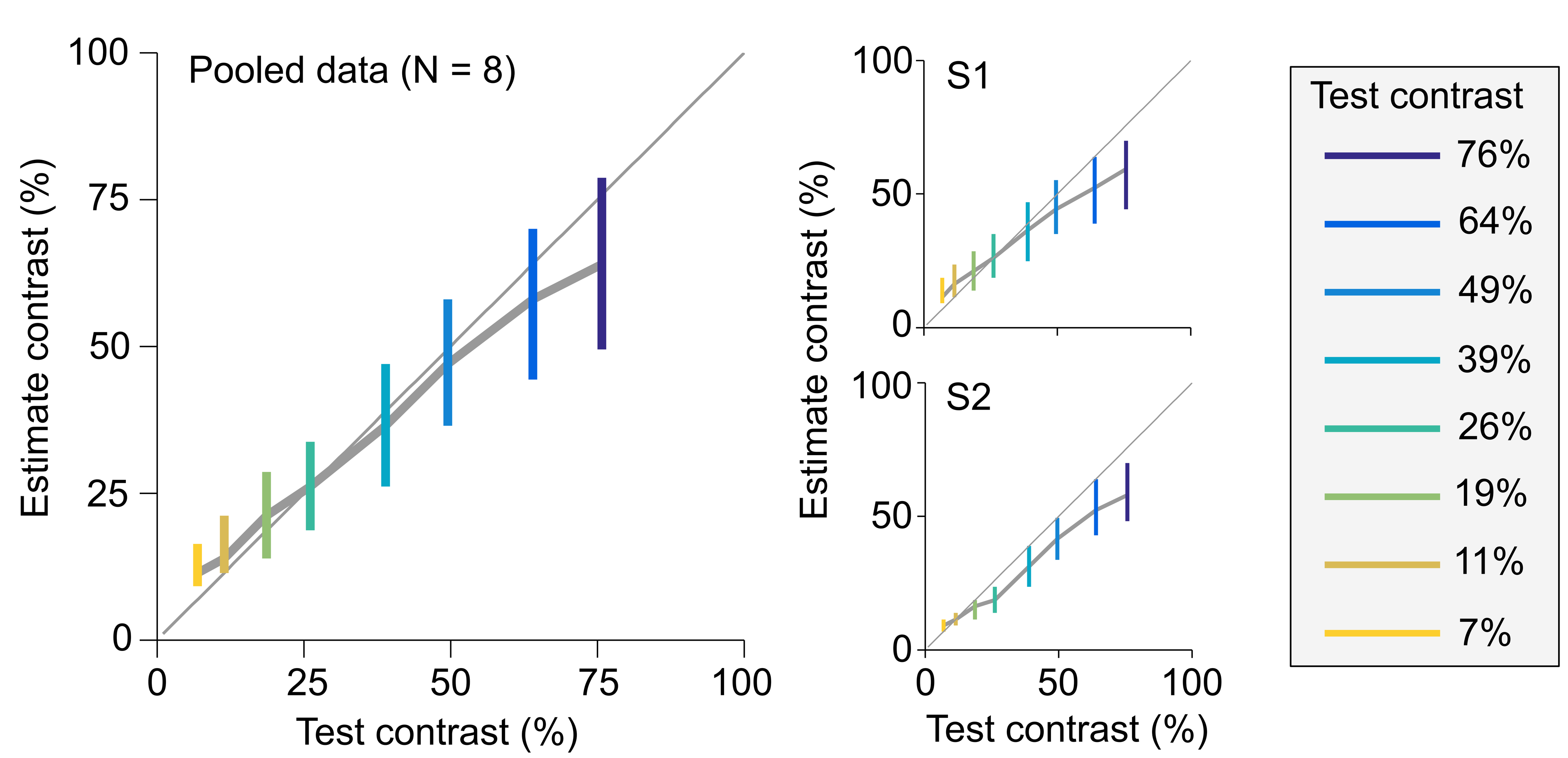
Task



- N = 8 observers, 1600 trials/observer
- Circular discs (1° diameter, 4° eccentricity)
- Adjust contrast of 2nd disc to match memory of 1st (using horizontal motions of mouse)
- 8 test contrasts (7-76%, Weber contrast)
- Gamma-corrected display (mean 45.4 cd/m^2)

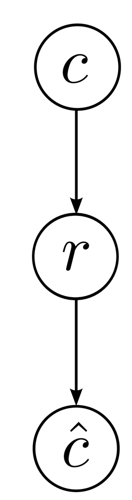
Results

Interquartile range of estimate distributions



- Distributions shifted with increasing test contrast, and were highly consistent across observers.

Encoding-decoding model



- We assume the stimulus contrast, c, is encoded in the summed spike count, r, of a population of Poisson neurons:

$$r \sim \mathrm{Poiss}(g(c))$$

- We allow the gain, g, to vary with contrast according to a Naka-Rushton equation:

$$g(c) = R_{\max} \frac{c^n}{c^n + {c_{50}}^n}$$

- Likelihood function:

$$p(r|c) = \frac{1}{r!} e^{-g(c)} g(c)^r$$

- Estimate contrast, $\hat{c}$, is given by (MLE):

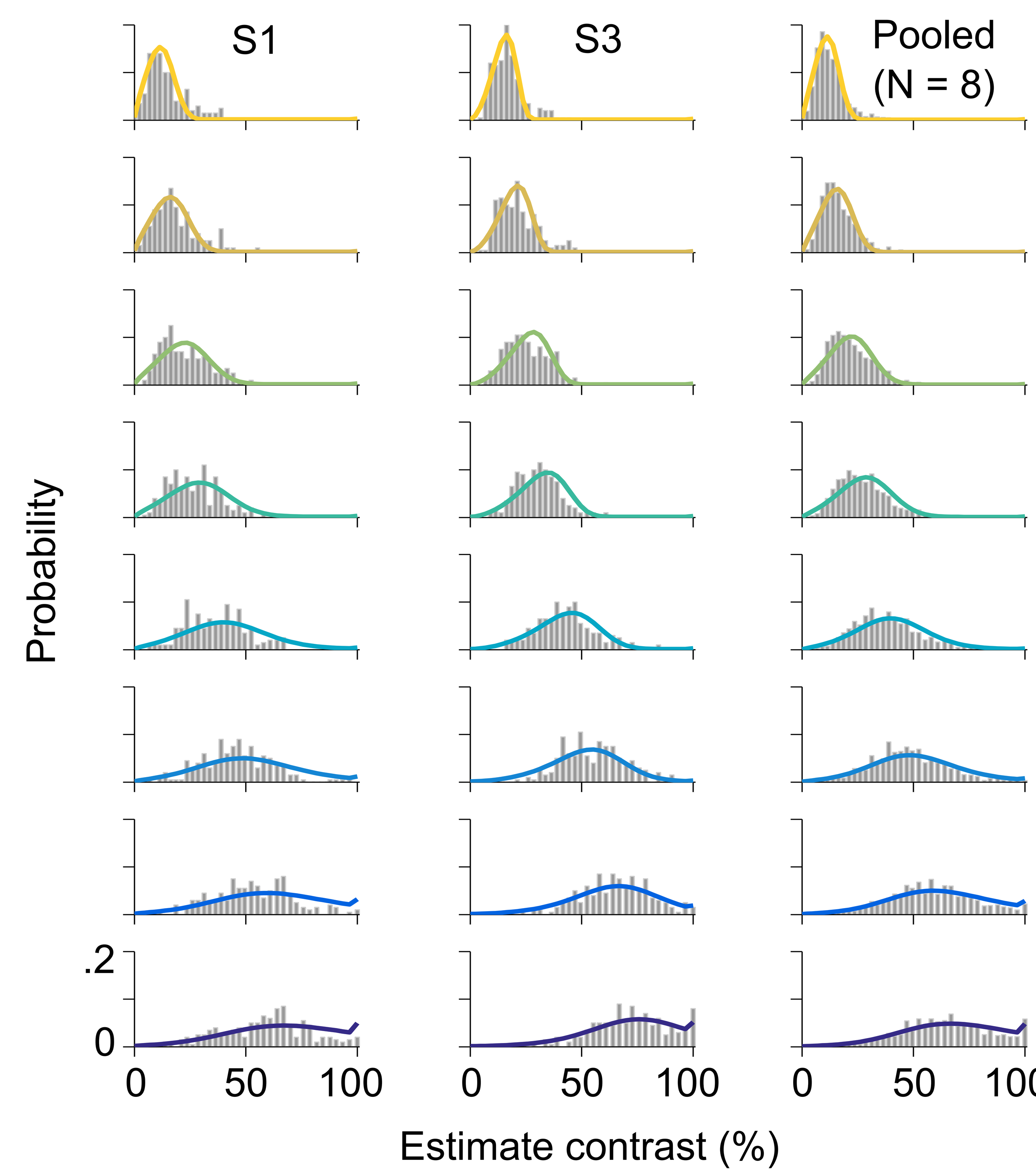
$$\hat{c} = \arg\max_c \left(-g(c) + r \log g(c) \right)$$

Model parameters

$R_{\max}$	maximum spike count
n	contrast exponent
c_{50}	semi-saturation term
λ	lapse-rate term

Model fits

- Model provided good quantitative fits to the distributions.



- Mean params (s.e.m.):

$R_{\max}$	13.23 (1.92)	c_{50}	0.71 (0.11)
n	2.07 (0.20)	λ	0.034 (0.007)

Conclusions

- Estimate distributions for luminance contrast have not previously been investigated using delayed estimation, and may provide rich information for testing theories of VSTM for luminance contrast.
- We measured these distributions and successfully characterized their shapes using a probabilistic model of neural responses.

Acknowledgements: This work was supported by NIH R01-EY020958 (to WJM). References: [1] Ma et al., Nat. Neurosci., 17: 347-356, 2014; [2] Magnussen & Greenlee, Psychol. Res., 62: 81-92, 1999.