Representation of visual uncertainty through neural gain variability

Olivier J. Hénaff, Zoe M. Boundy-Singer, Kristof Meding, Corey M. Ziemba & Robbe L. T. Goris

Jiaxin Wang
04/23/2021

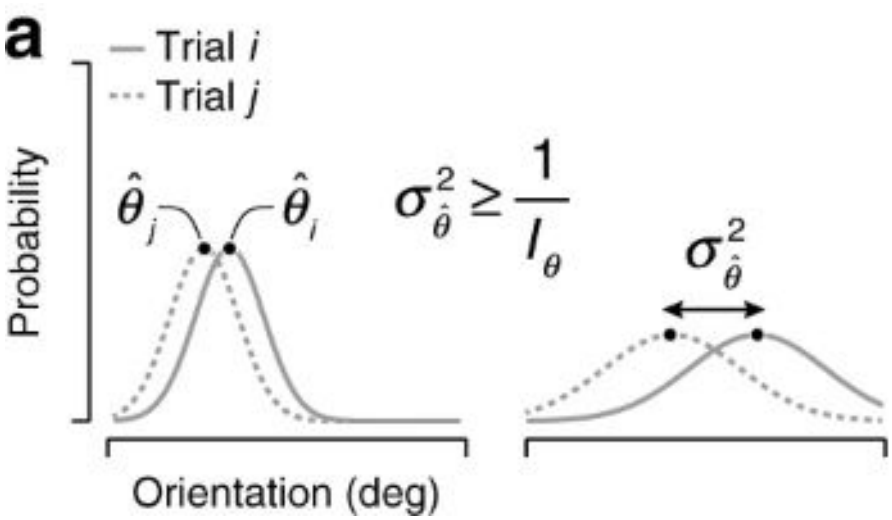
Introduction

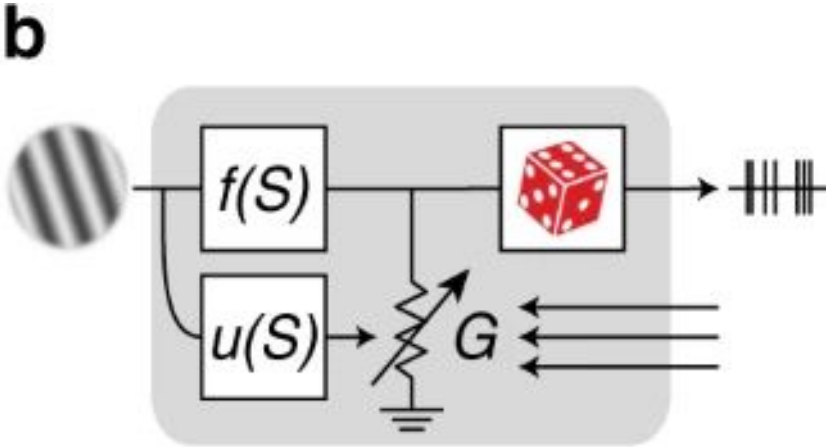
- **Model:** average neural response strength encodes stimulus features, while cross-neuron variability in response gain encodes the uncertainty of these features

- **Experiments:** spiking activity in macaque V1 and V2 by repeated presentations of stimuli whose uncertainty was manipulated in distinct ways

- **Finding:** gain variability of individual neurons is tuned to stimulus uncertainty.

Model 1

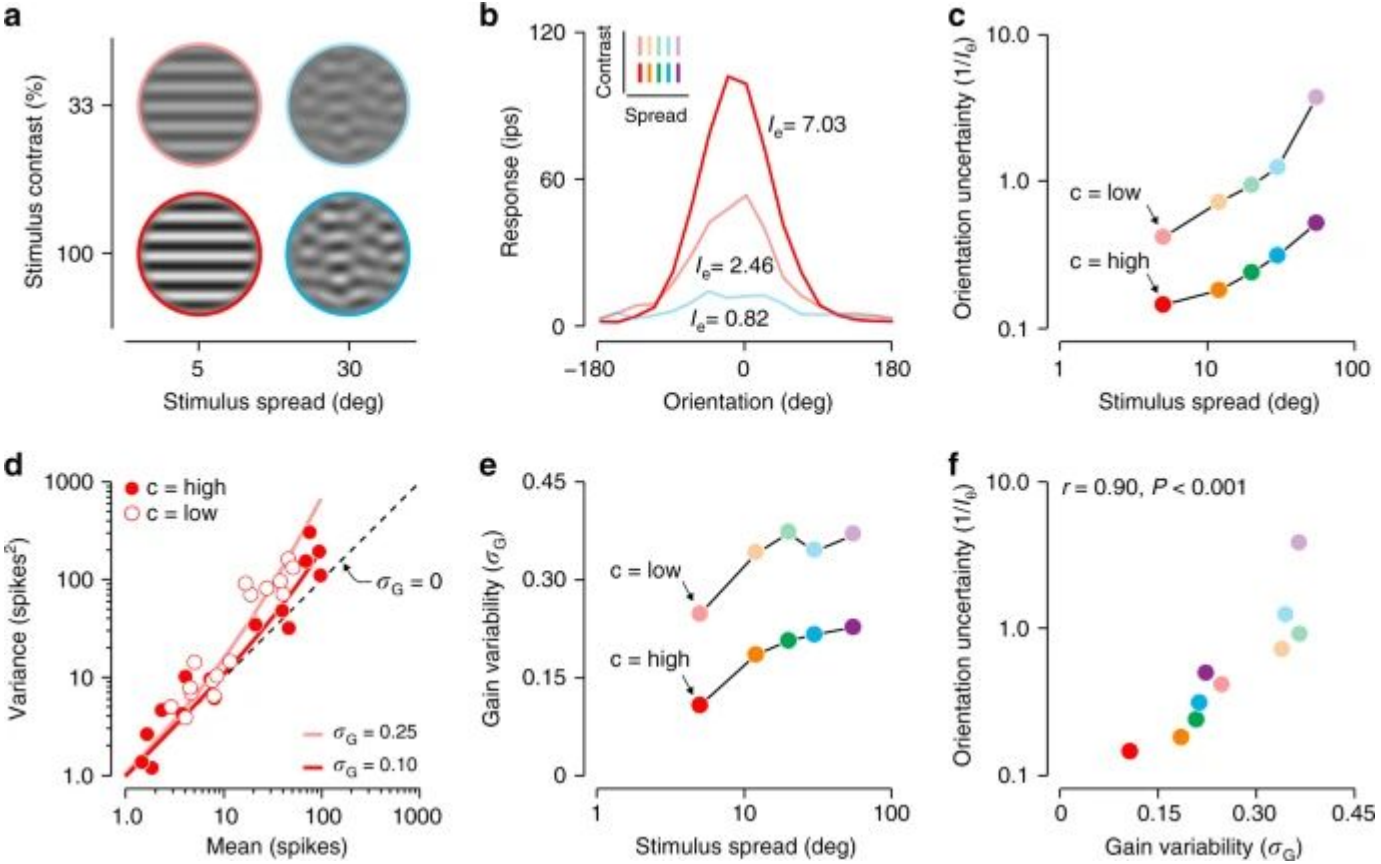




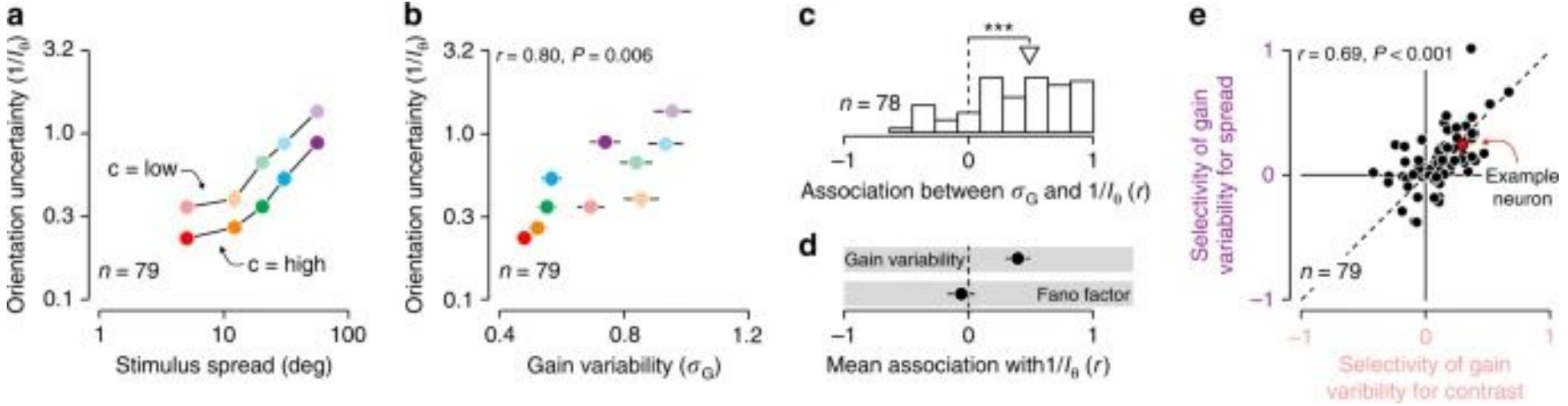
If gain G has a unit mean and varies on a time-scale which is slow relative to the measurement interval Δt, variance of spike count K is

$$\mathrm{Var}[K|S,\Delta t] = f(S)\Delta t + \sigma_G^2 (f(S)\Delta t)^2.$$

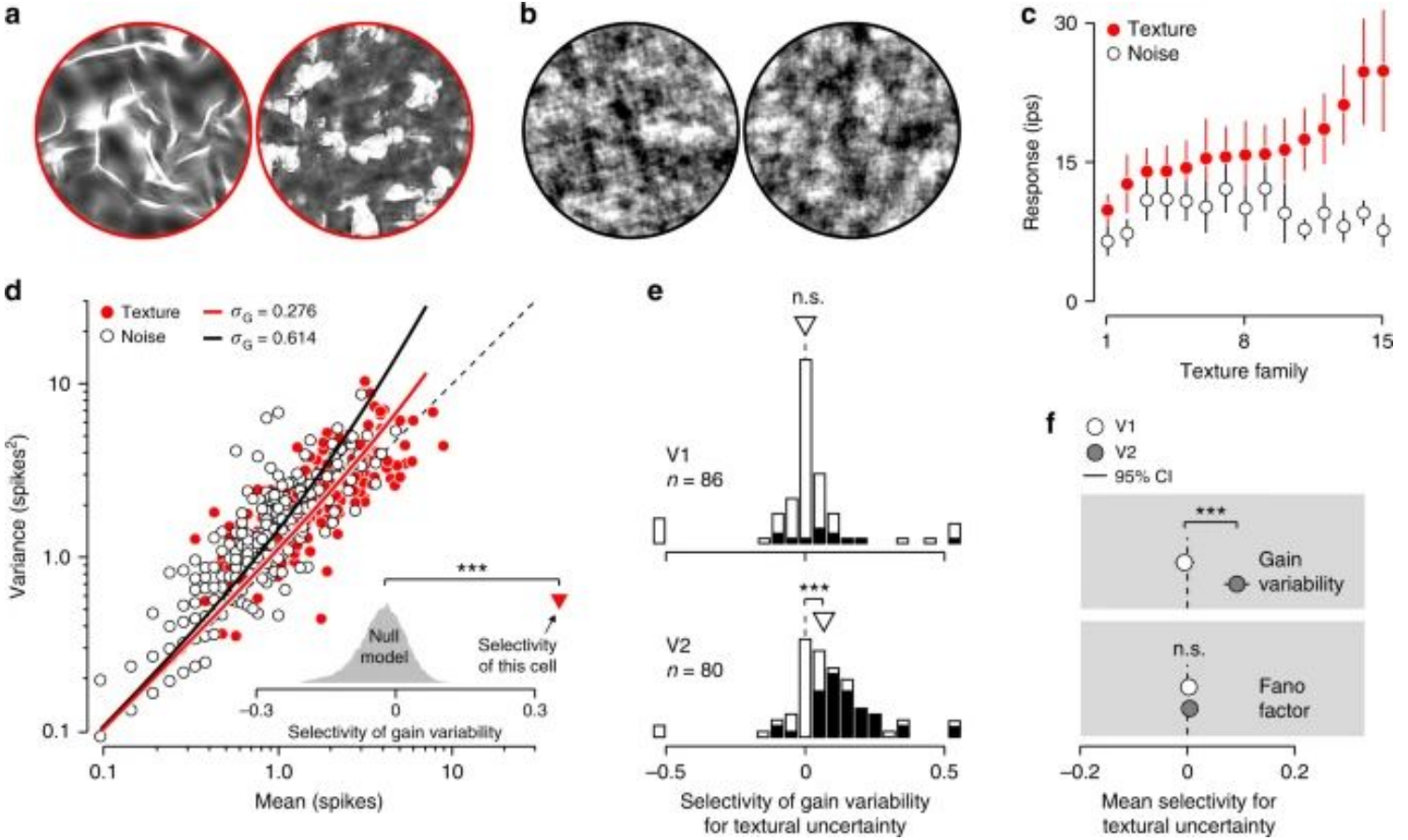
Experiment 1 : single neuron



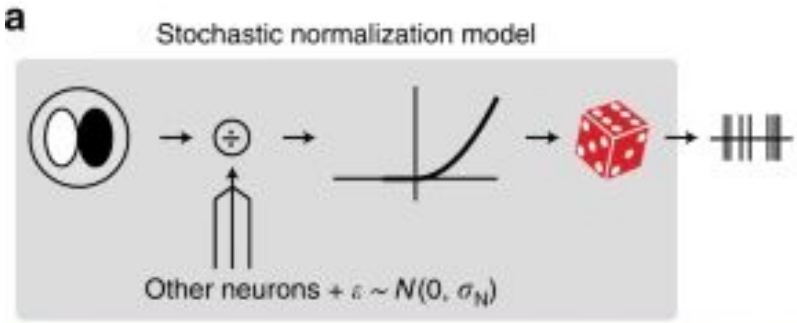
Experiment 2 : neuron population



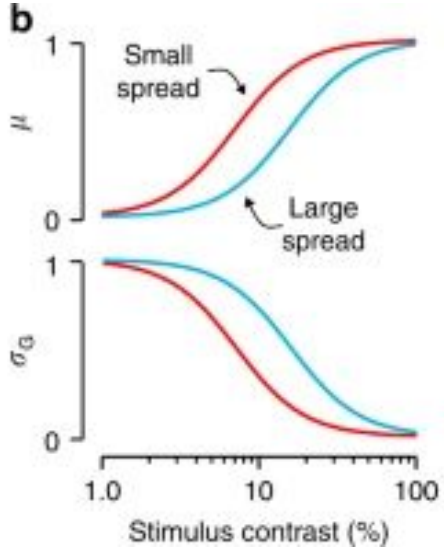
Experiment 3 : other feature

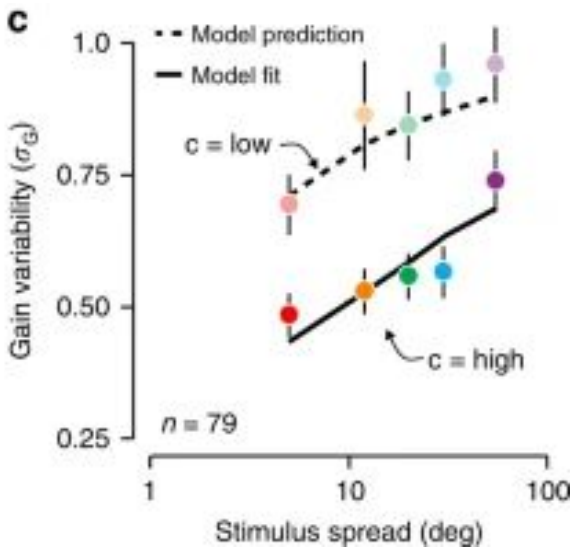


Model 2: Normalization

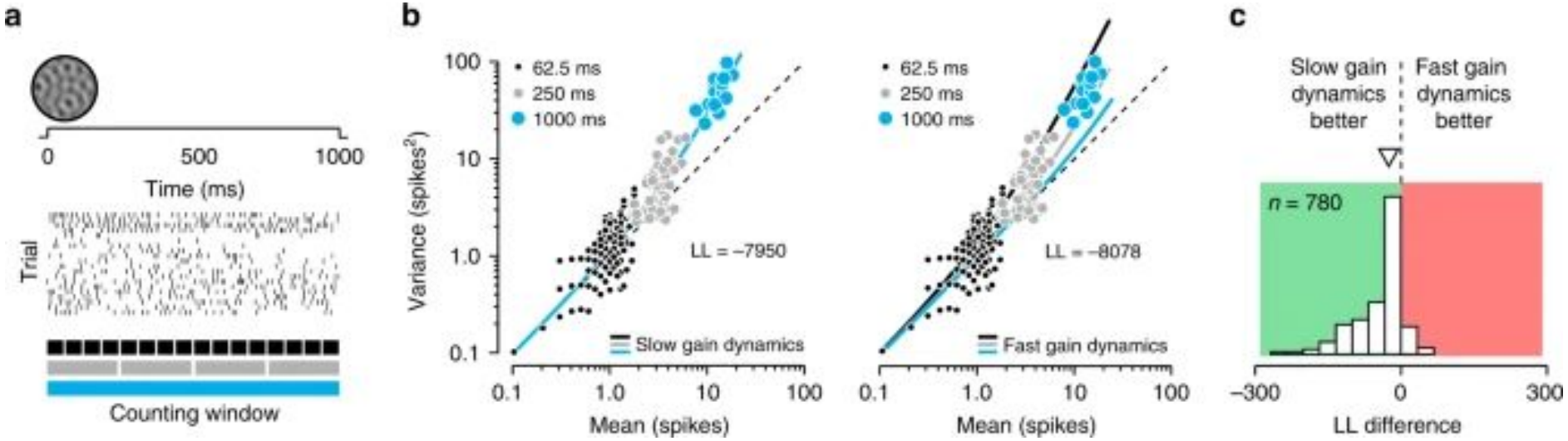


$$f(S) = \left(\frac{g(S)}{\beta + \sum_j g_j(S)} \right)^p \qquad \sigma_G = \frac{\sigma_N \cdot p}{\beta + \sum_j g_j(S)}$$

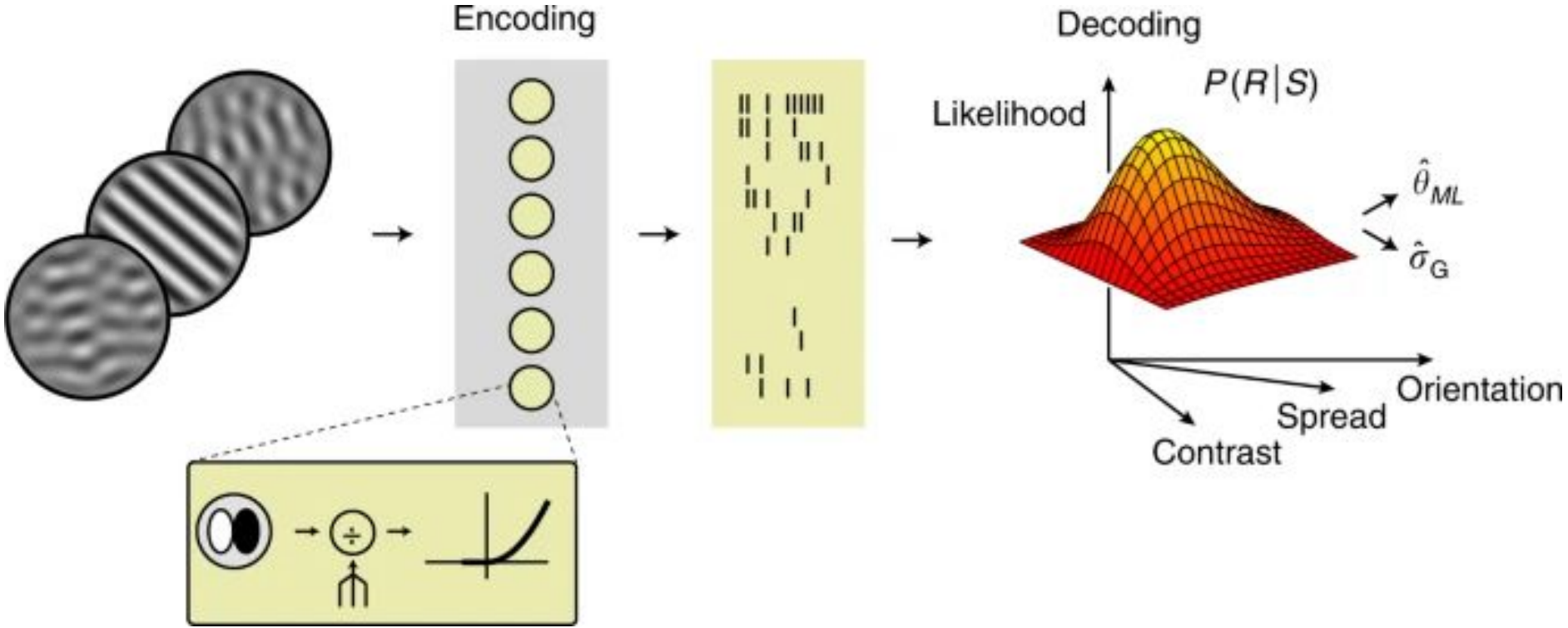




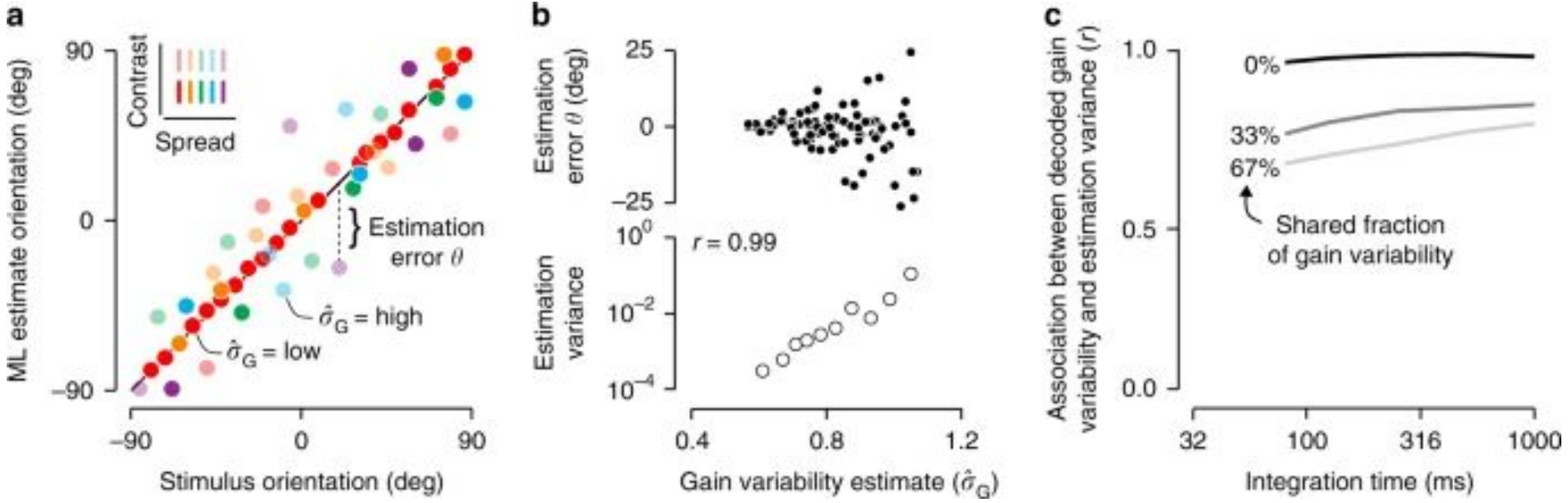
Experiment 4 : slow or fast dynamics



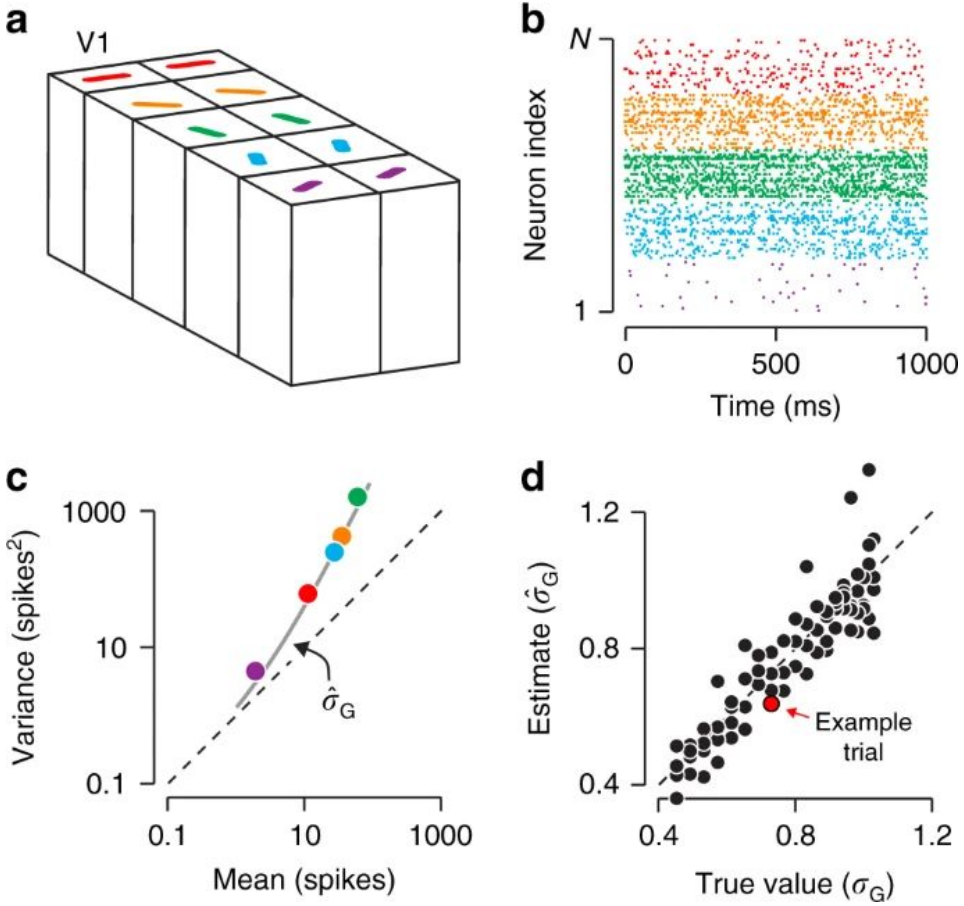
Method : Decoding uncertainty from neural activity



Experiment 5 : Quantitative performance



Model 3: How circuits decode gain variability



Discussion

- Proposed a new model of canonical computation in sensory cortex

- Our approach can directly be extended to other stimulus features, visual areas, and sensory systems to investigate the generality of the uncertainty receptive field.

- Estimating interneuronal gain variability allows a decoder to infer stimulus uncertainty without detailed knowledge of the sensory neurons' classical receptive field.