Neural circuits for cognition

Fisher Information, neural population codes, and the grid code

MIT Course 9.49/9.490

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Reminders/Announcements

- Please fill out course evaluations!

- Project reports: Due Dec 10, 4-5 pages, with motivation/introduction, methods, results, figures, discussion, citations: single PDF. Also submit any code (separately).

Fisher information

- Why does the brain have large populations encoding the same variable? E.g. ~2000 HD cells?

- Given redundancy, can encode information in many possible ways. Why does the brain make a particular choice?

- Given spikes from neurons and an unbiased decoder of an encoded variable, what can I say about the variance/squared error of this decoder?

Population codes enable accurate representation of variables with noisy elements
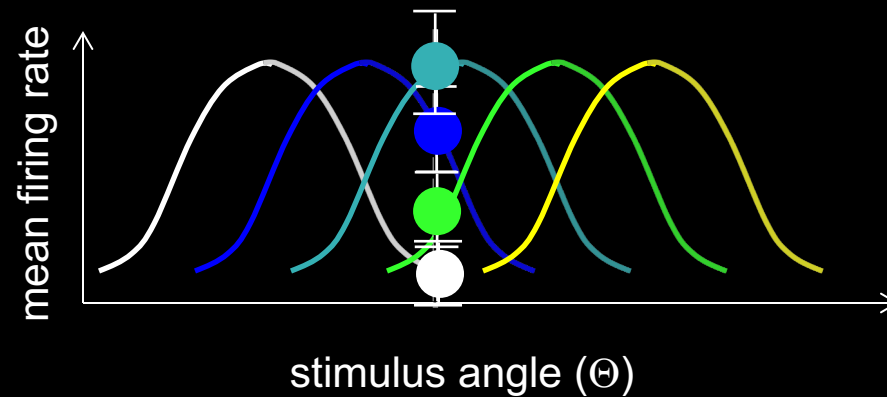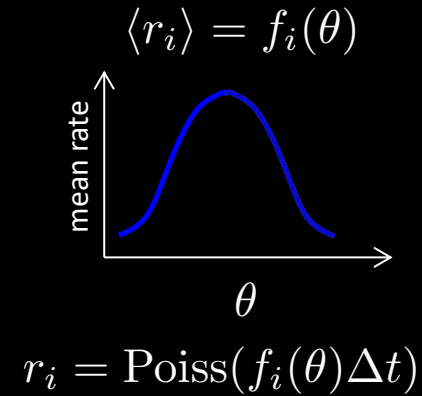

e.g. V1 orientation tuning.
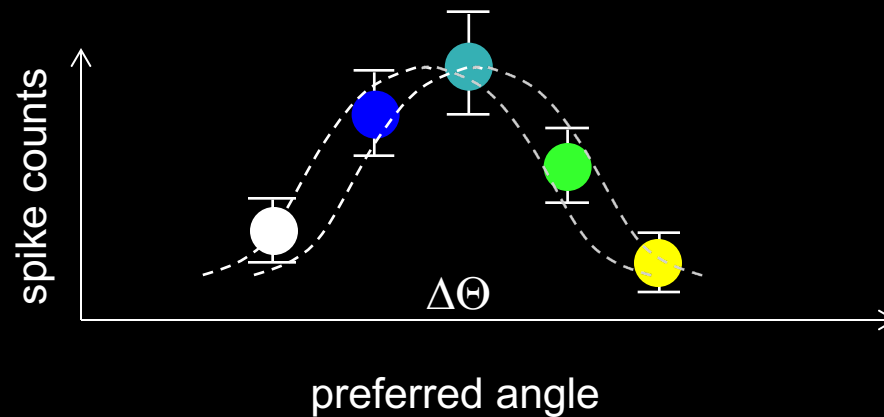
Many neurons firing at each value of variable: smaller total estimation error.

Error in estimating encoded variable from population response

$$\theta \rightarrow \mathbf{r} \rightarrow \hat{\theta}$$

$$MSE \equiv \langle(\hat{\theta} - \theta)^2\rangle = ?$$

$$\langle r_i \rangle = f_i(\theta)$$

$$r_i = \text{Poiss}(f_i(\theta)\Delta t)$$

On the board….

FI definition, examples, derivations.
The notion of Fisher-optimal tuning curves.
Optimal tuning widths for bump-like codes.

Are neural tuning curves Fisher-optimal? Thalamic HD code

Chaudhuri et al., 2019

Combination of truly 1D coding and finite tuning width suggests that Fisher-optimality is NOT the governing factor in neural tuning.

Summary of neural coding

- Fisher Information quantifies the curvature (sensitivity) of a model to variations in its parameters or, in a coding context, quantifies how accurately one can discriminate the value of an encoded variable.

- Fisher information provides a lower-bounded on squared error of unbiased estimators, the bound typically useful in the asymptotic limit.

- A set of N conditionally independent neurons with homogeneous tuning, each with finite dynamical range, encodes ~N states of a continuous variable (dynamic range, FI that grow as N).