Unsupervised Sparse Deconvolutional Learning of Abstract Features Driving Neural Activity

Website



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from [2].

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- We deconvolve single-trial activity into interpretable components using algorithm unrolling [1].
- Reward prediction error responses of **dopamine** neurons are modulated by two components, salience and value [2].
- We deconvolve the two factors in an unsupervised manner and attribute a kernel and a code to each factor.
- We show that the **inferred codes** are more **informative** than firing rates estimated using ad-hoc windows.

Methods



Model firing rates at trial j with K kernels characterizing neurons' responses to time-sensitive sparse events [3].

Generative Model:
$$\mu^{j} = g(\sum_{k=1}^{K} \mathbf{h}_{k} * \mathbf{x}^{j,k} + a^{j})$$

firing rate dictionary events and strength baseline dictionary events and strength baseline dictivity
Observations:
$$\mathbf{y}^{j}|\{\mathbf{h}_{k}, \mathbf{x}^{j,k}\}_{k=1}^{K} \sim \text{Binomial or Gaussian with mean } \mu^{j}$$

Optimization:
$$\min_{\{\mathbf{h}_{k}\}_{k=1}^{K}, \{\mathbf{x}^{j,k}\}_{j,k=1}^{J}} \sum_{j=1}^{J} -\log P(\mathbf{y}^{j}|\{\mathbf{h}_{k}, \mathbf{x}^{j,k}\}_{k=1}^{K}) + \sum_{k=1}^{K} \lambda \|\mathbf{x}^{j,k}\|_{1} \text{ s.t. } \|\mathbf{h}_{k}\|_{2} = 1$$

Results
a Surprise Expected **b** Order Cue Reward L (Salience) Reward H (Value) **C** Spearman Correlation



We study 40 optogenetically identified dopaminergic neurons recorded in a classical conditioning task [4].
a) Surprise trials: a reward was delivered without cue. Expected trials: an odor cue preceded reward delivery.
b) (top) Kernels: characterizing the neural response. (bottom) Codes: a measure of neurons' tuning to reward amount.
c) Value codes carry more information about reward amount than the firing rates over ad-hoc windows.

d) Value codes across the neural population show a diverse sensitivity to reward size.

Model Characterization



Learn kernel Code amplitude recovery error Kernel recovery error 1.0 timing 2 timing [ms]ms 0.5size size Unknown Known Bin 25 Bin 0.050 8 11 14 17 20 11 14 17 20 8 2 5 Background firing rate [Hz] Background firing rate [Hz]

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