Adaptation to stimulus statistics links spontaneous activity to the structure of orientation

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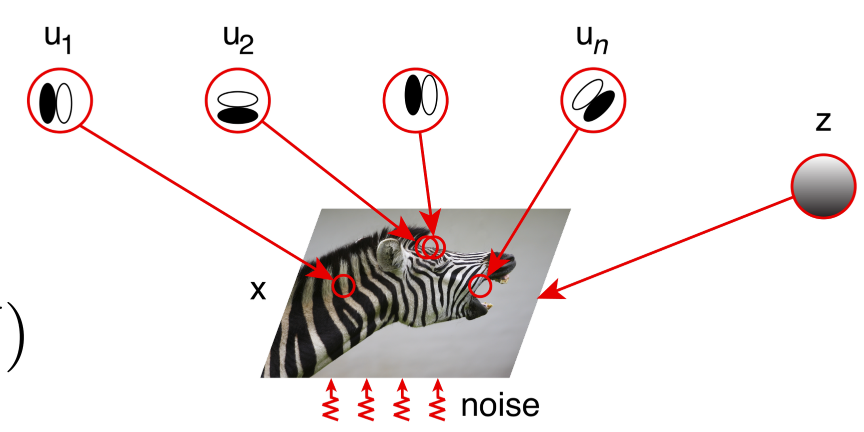
Evoked and spontaneous activity in the visual cortex

- presence of travelling waves in immature V1 indicates a structure eliciting stimulus-independent correlations
- stimulus-independent (spontaneous) activity statistics represents prior beliefs about receptive field co-activations
- posterior distribution of features to represents uncertainty
- what do structural correlations imply about orientation selectivity?

A nonlinear model of receptive fields

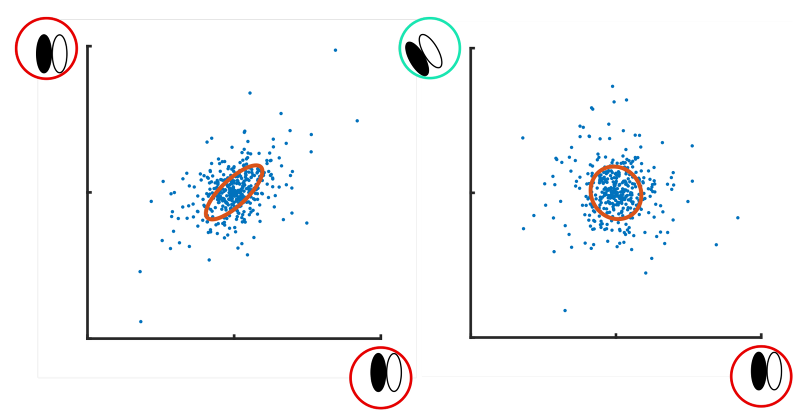
- in a Gaussian Scale Mixture model, an image is decomposed as the linear combination of edge filters, together with a global contrast and observation noise



$$p(x \mid u, z) = (x; zAu, \sigma_x^2 I)$$

- activations of filters on natural images are not independent. Similarly tuned filters correlate more, indicating stronger connections between corresponding cells

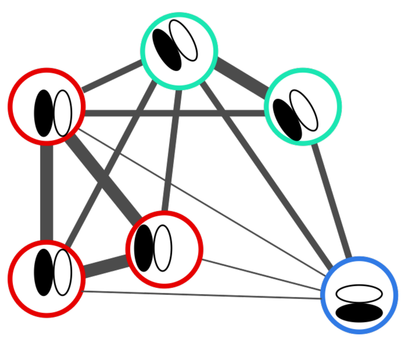
Mean filter coefficients

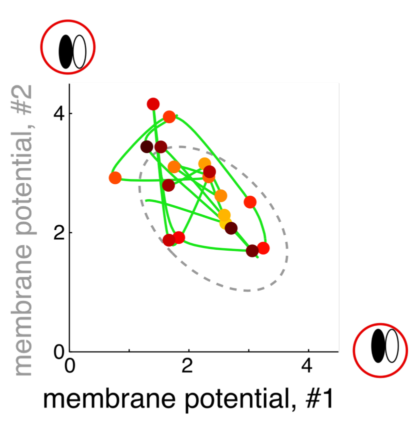


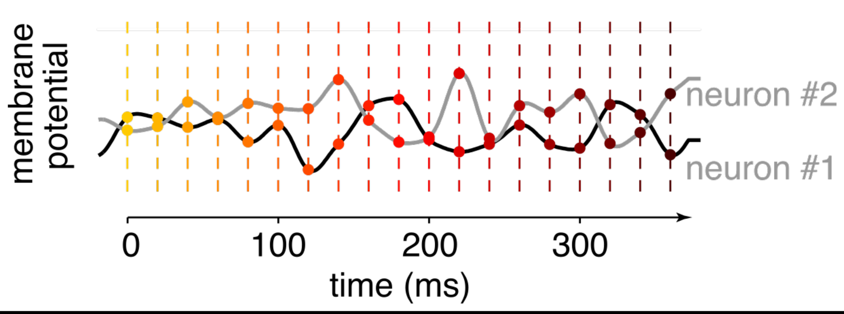
- GSM represents filter correlations through a prior covariance matrix

$$p(u) = (u; 0, C)$$

- the prior covariance of filters can be learned from natural stimuli by a Maximum Likelihood scheme



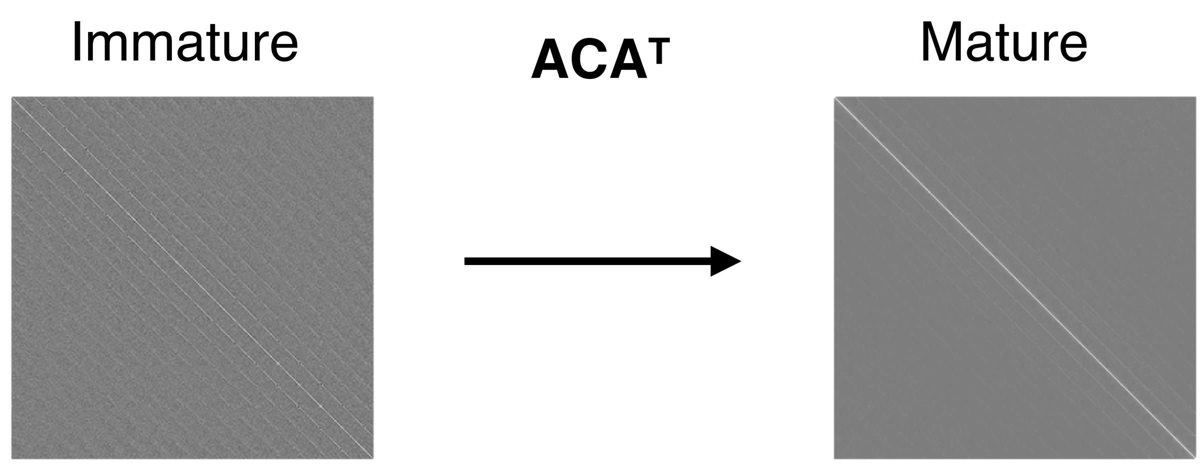




Learning receptive fields for a predefined correlational structure

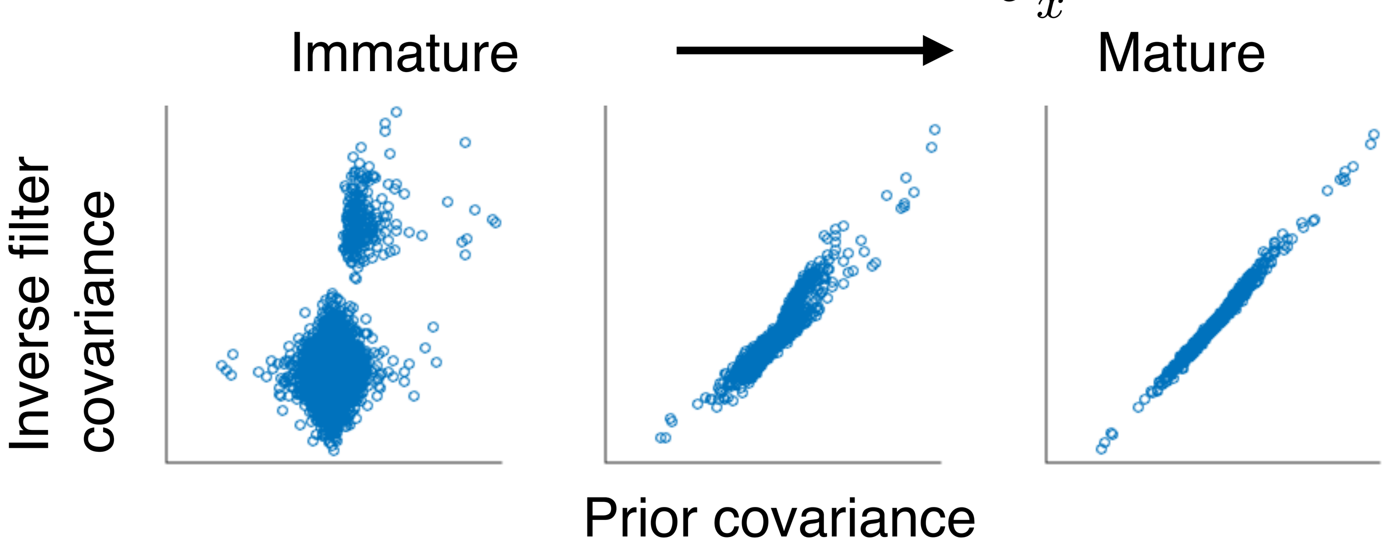
- as the stimulus set is whitened, the predictive distribution of pixels implies that ML learning will bring ACA^T closer to diagonal

$$p(x \mid z) = \mathcal{N}(x; 0, \sigma_x^2 I + z^2 ACA^T)$$



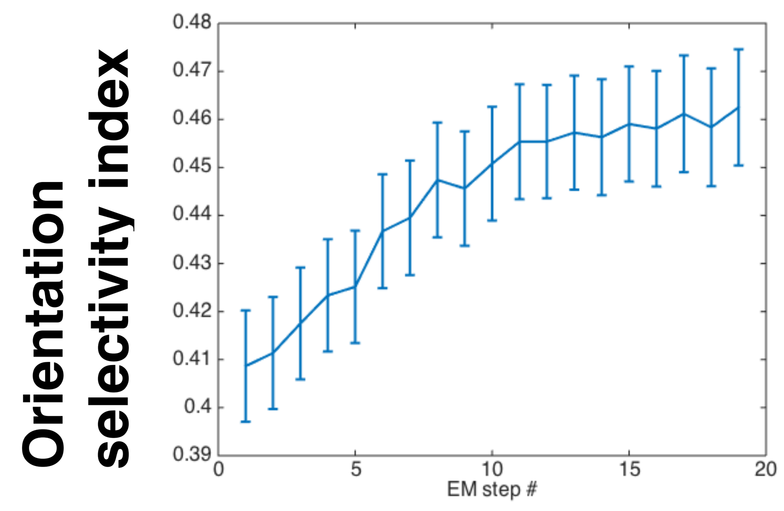
- in inference, the prior and the inverse of the filter covariance make up the posterior (noise) covariance, thus ML will make them similar

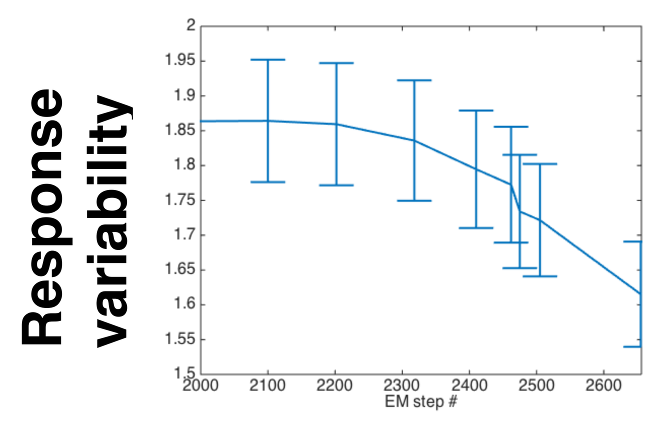
$$p(u \mid z, x) = \mathcal{N}(x; \mu_u, C^{-1} + \frac{z^2}{\sigma_x^2} A^T A)^{-1}$$



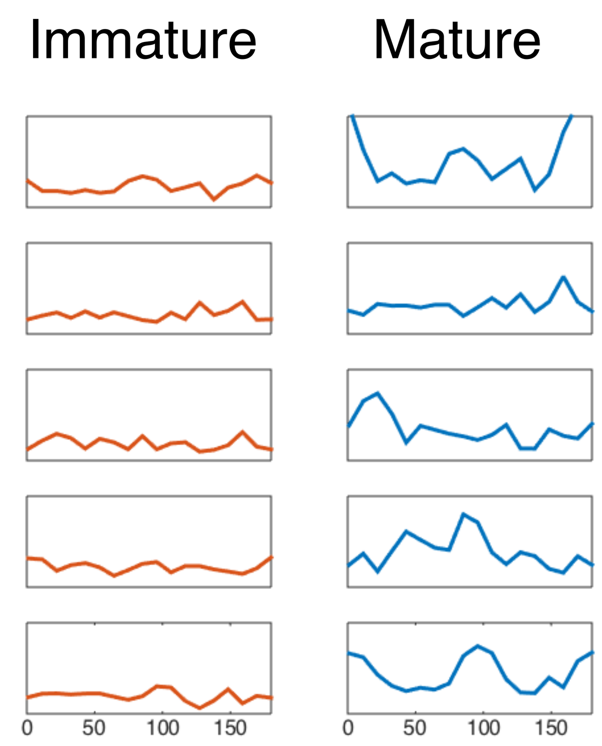
Properties of learned receptive fields

- when using natural images as the training set, additional to the general effects of learning we see that
  - orientation selectivities of the learned filters increase
  - the variability of responses to natural images decreases



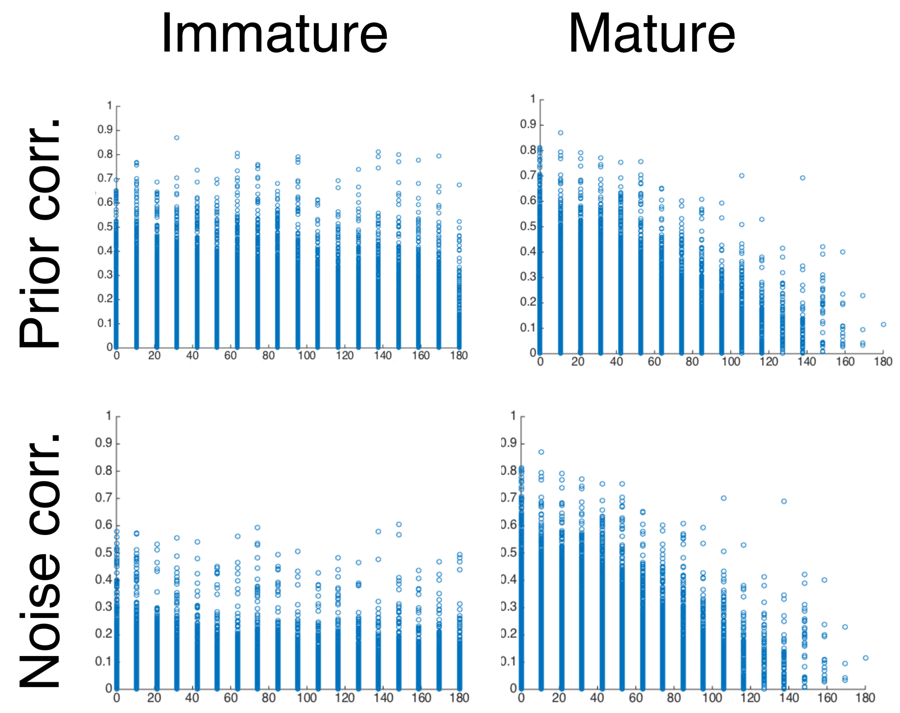


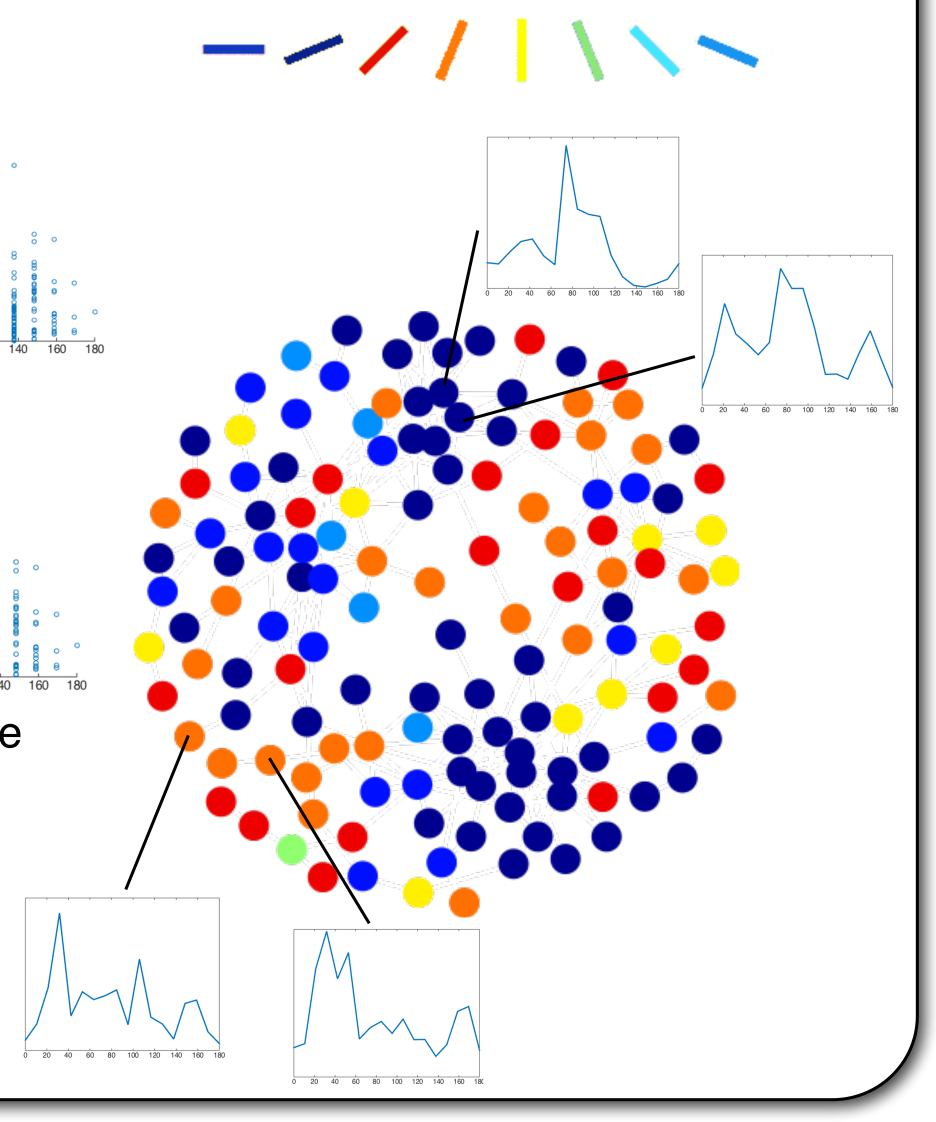
Tuning curves



Orientation preference topology induced by local connectivity

- prior correlation induces similar orientation tunings during learning
- noise correlations are inversely proportional to differences in tuning
- when arranging cells according to the correlational structure, we see patches of orientation preference





Conclusions

- Lateral connectivity defines the formation of orientation maps from eye opening
- Adaptation to natural images in a model of receptive field correlations reproduces properties of visual orientation maps
- Noise correlations may change by adaptation of receptive fields, leaving lateral connectivity unchanged

Acknowledgement

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