The contribution of response correlations to the neural code of V1

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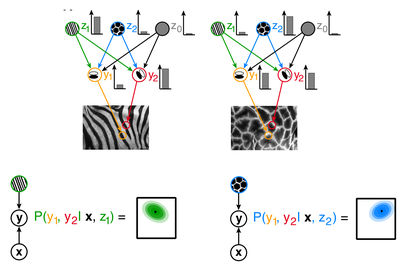
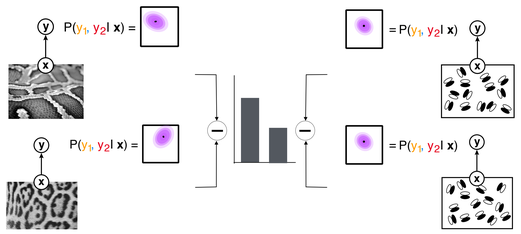
Stimulus content shapes correlations

- vision is understood as inference in a hierarchical probabilistic model of natural stimuli
- perception of latent features in an observed stimulus is implemented as the representation of the posterior distribution of the feature
- the shape of the posterior distribution depends on both the stimulus and the inferred higher-level features

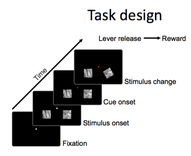


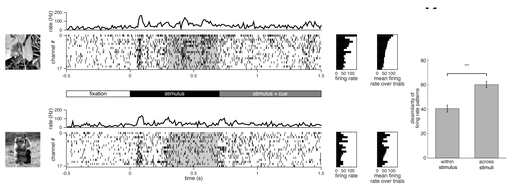
- V1 simple cells represent oriented edge features, while extrastriatal neurons represent complex visual features
- neural activity correlations in V1 are predicted to differ more when the inferred higher-level content of the stimuli are different



Experimental paradigm

- electrode arrays in the V1 of two macaques
- multiunit spike trains
- task-engaged animals: attention task
- task design for reliable correlation assessment: 6/8 stimuli, 13 sessions, 600-1000 trials

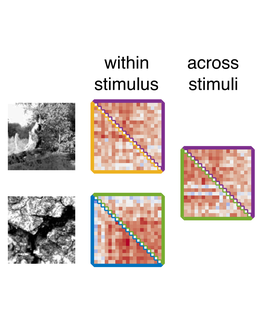




Stimulus-dependence of correlations

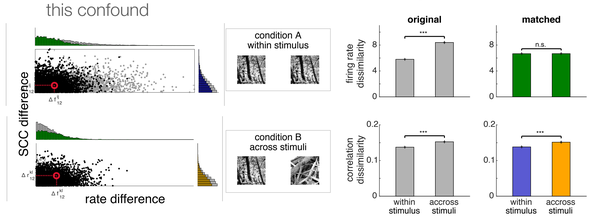
In order to assess the stimulus-specificity of detailed correlation patterns, the dissimilarity of spike count correlations (SCC) are assessed

- across stimuli
- within stimulus, variation due to finite sample size

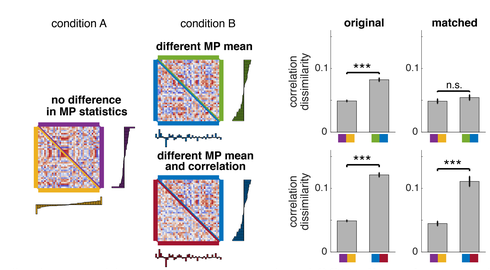


Contrastive rate matching

- changes in firing rate might confound the measurement of the magnitude of SCCs such that stimulus-specific of firing rates might cause stimulus-specificity in SCCs
- matching the distribution of rates via subsampling the data controls for this confound



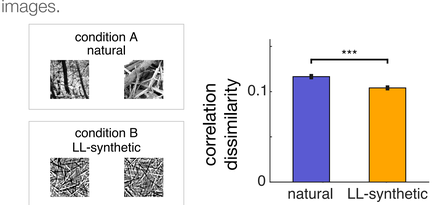
- simulated spike trains are used to assess the effectiveness of CRM
- in different conditions we can individually control for changes in firing rates and correlations



Distribution matching removes mean-related SCC effects from simulated spike trains, but not top-down effects.

Correlation specificity modulation

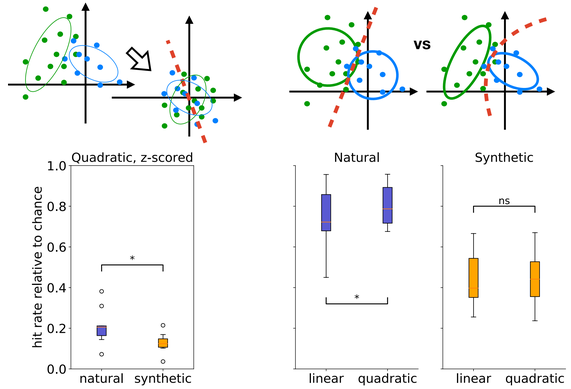
Synthetic images that consist of different oriented edges but do not have any higher-order statistical structure (LL-synthetic) are compared to natural images.



SCCs differ more in response to natural stimuli than to LL-synthetic stimuli, as predicted by the hierarchical inference model.

Role of correlations in decoding

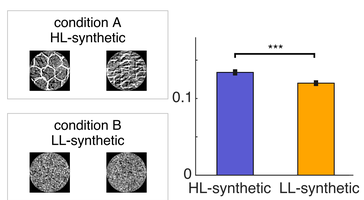
- logistic regression on z-scored data
- linear and quadratic mixture of Gaussian decoders



Correlations contribute to the decidability of natural, but not LL images.

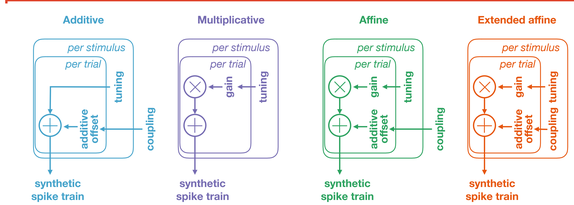
Probing intermediate representations

- Stimuli from independent oriented edges (LL)
- Synthetic stimuli with correlations between the oriented edges derived from texture patterns, shown to elicit differential response in V2.

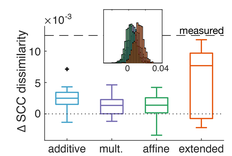


SCCs differ more in response to HL-synthetic than to LL-synthetic stimuli, suggesting that second-order texture statistics are represented in the visual cortex as latent variables.

Affine model

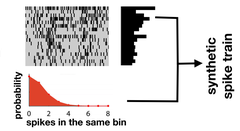


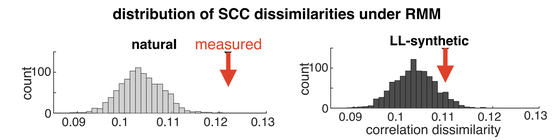
- Phenomenological models with additive and multiplicative terms do not reproduce the content modulation of SCC specificity
- Augmenting the affine model with stimulus-specific coupling reintroduces the modulation



Raster marginal model

- The raster marginal model (RMM) generates SCCs based on the finite number of bins used to compute them
- Measured SCC specificities in response to natural images are very unlikely under the RMM





Conclusions

- the hierarchical inference model of perception predicts the stimulus-dependence of population activity statistics (correlations)
- the stimulus-specificity of correlations depends on stimulus structure: it is attenuated for stimuli lacking high-level structure
- specific correlation patterns in V1 support a sampling-based neural representation

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