Population codes in V1 and MT are optimised for the structure of natural images

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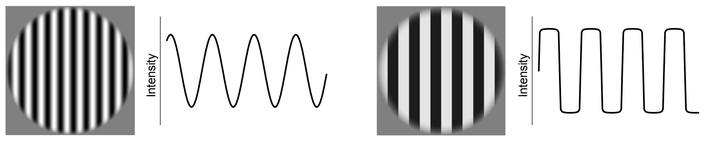
Many neurons in the primary visual cortex (V1) project to the middle temporal area (MT). In V1, motion representations are tightly coupled to the physical properties of the stimulus. In MT, a more robust, stimulus invariant, representation of motion direction is computed.

Here, we examine how networks of neurons in striate + extra striate cortex change their representations of different kinds of stimulus structure.

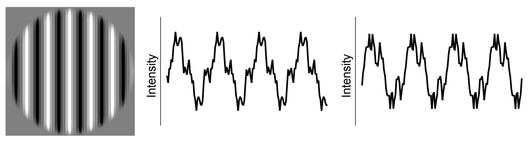
Manipulating stimulus structure

Sine wave: narrowband

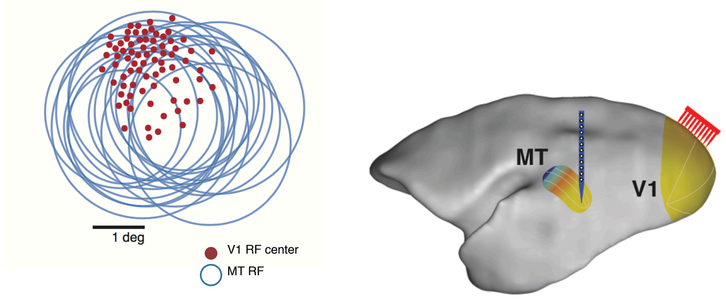
Square wave: broadband structure



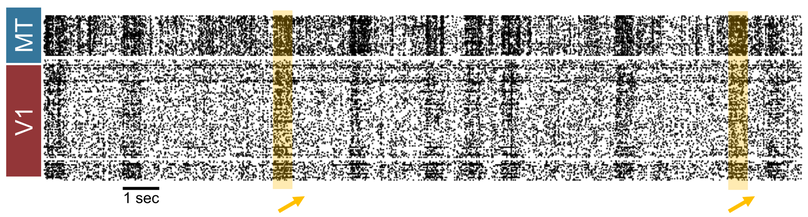
Phase-randomised square wave: broadband, unstructured



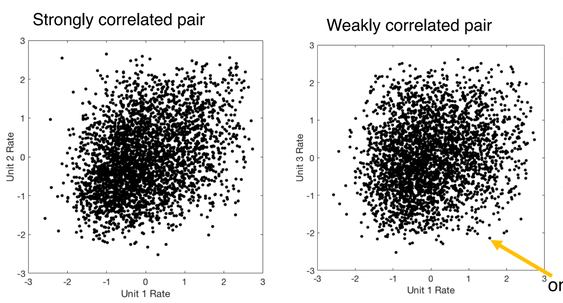
Population electrophysiology



5 animals
96 channels in V1 (1 implant per case)
32 channels in MT (1-4 implants per case, 10 total)



Spike-count correlations



- Rates are integrated over 500 ms response window
- Z-scores are computed for each direction
- Z-scores are de-trended based on slow 20-trial mean and standard deviation

Data are from:
8,429 V1-V1 pairs
3,765 MT-MT pairs
17,403 V1-MT pairs

Average correlations between pairs of neurons are > 0

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(Overly) simplified network results

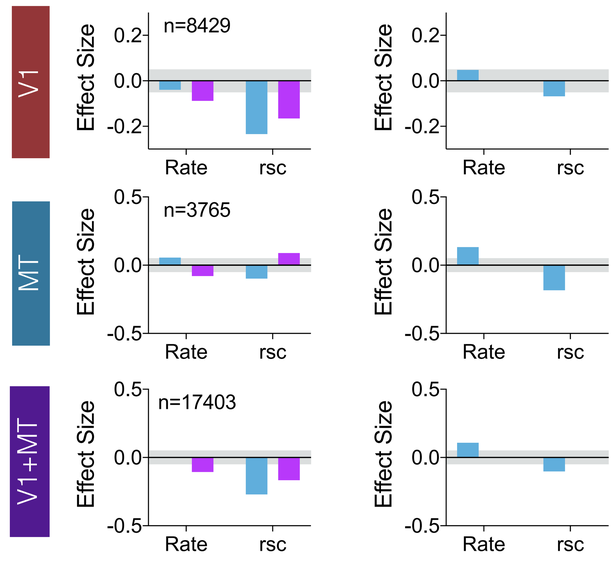
Begin by treating V1 and MT as entirely homogeneous populations

Bandwidth

What is the effect of adding more frequencies (**aligned** or **not**), relative to a sine wave stimulus?

Alignment

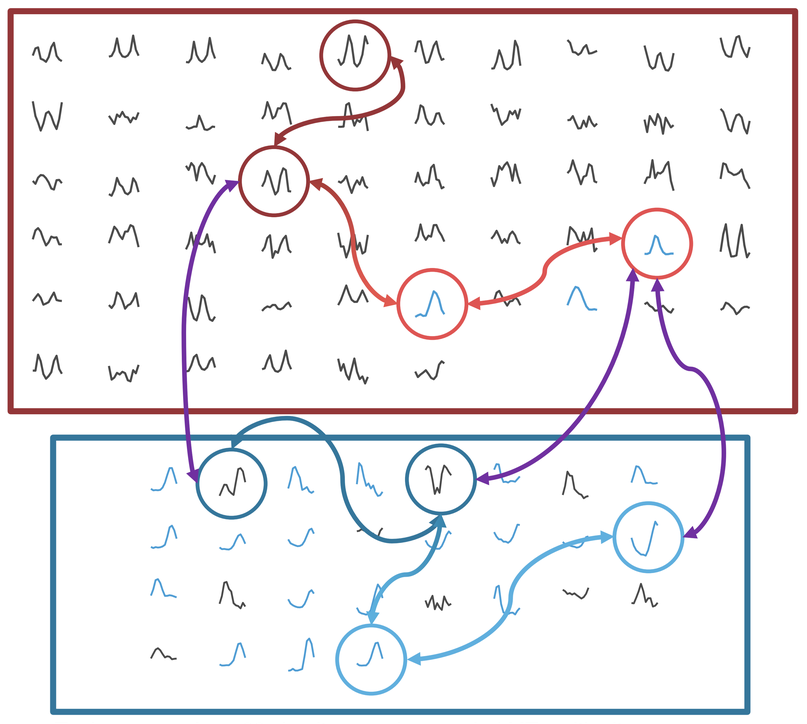
What is the effect of adding **phase alignments** relative to a randomised square wave?



Both features of natural images: broadband spectral content, and phase alignments within that content, tend to reduce spike count correlations.

Networks based on direction selectivity

Tuning curves from 56 simultaneously recorded V1 multiunits



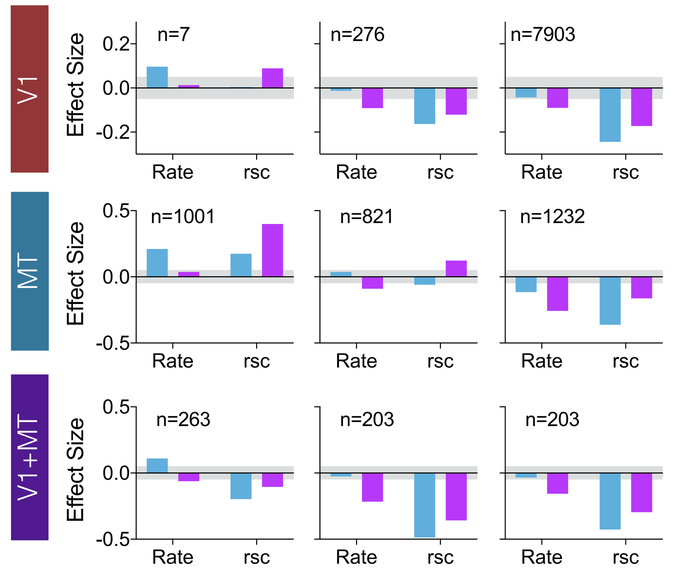
Tuning curves from 28 simultaneously recorded MT multiunits

Does structure interact with selectivity?

Pairs of neurons in and between V1 and MT have been grouped depending on whether they are both direction selective (both DS), one neuron is direction selective (one DS), or both are orientation selective (no DS).

Bandwidth

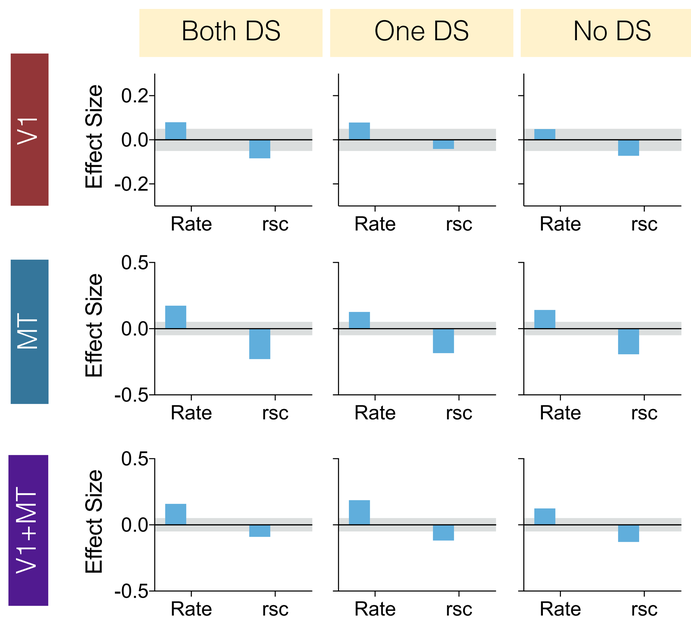
What is the effect of adding more frequencies (**aligned** or **not**), relative to a sine wave stimulus?



Broadband images, especially square waves, usually evoke activity with lower correlations.

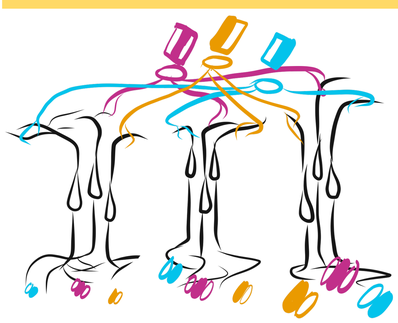
Phase Alignment

What is the effect of adding **phase alignments** relative to a randomised square wave?



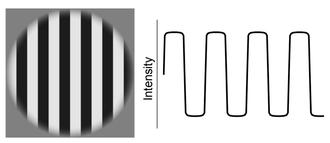
Phase-aligned images consistently evoke activity with lower correlations.

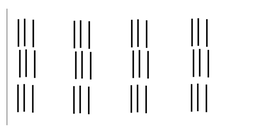
What might produce these effects?



Normalisation pools that are specific for phase and orientation, but span many spatial frequencies

OR





Lower correlations may be promoted by patterns such as square waves because they evoke cross-scale synchronous firing