Network structure within and between marmoset V1 and MT facilitates natural image coding

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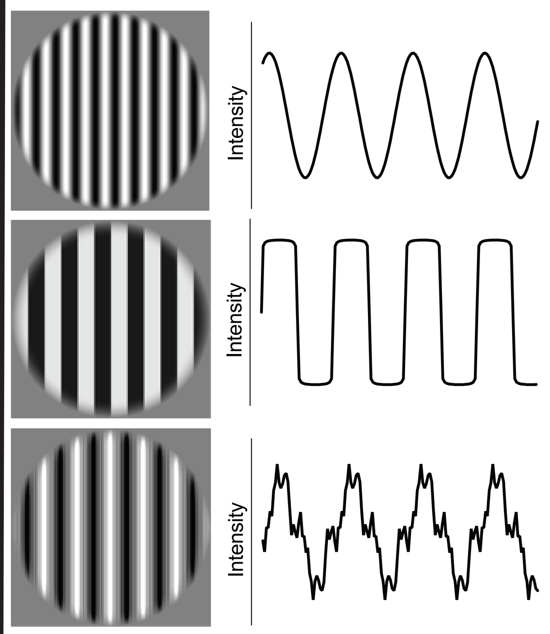
Many neurons in the primary visual cortex (V1) project to the middle temporal area (MT). In V1, motion representations are tightly coupled to the physical properties of the stimulus. In MT, a more robust, stimulus invariant, representation of motion direction is computed.

Here we examine how stimulus representations in networks of neurons in two cortical areas depend on stimulus structure.

METHODS

1. Manipulating stimulus structure



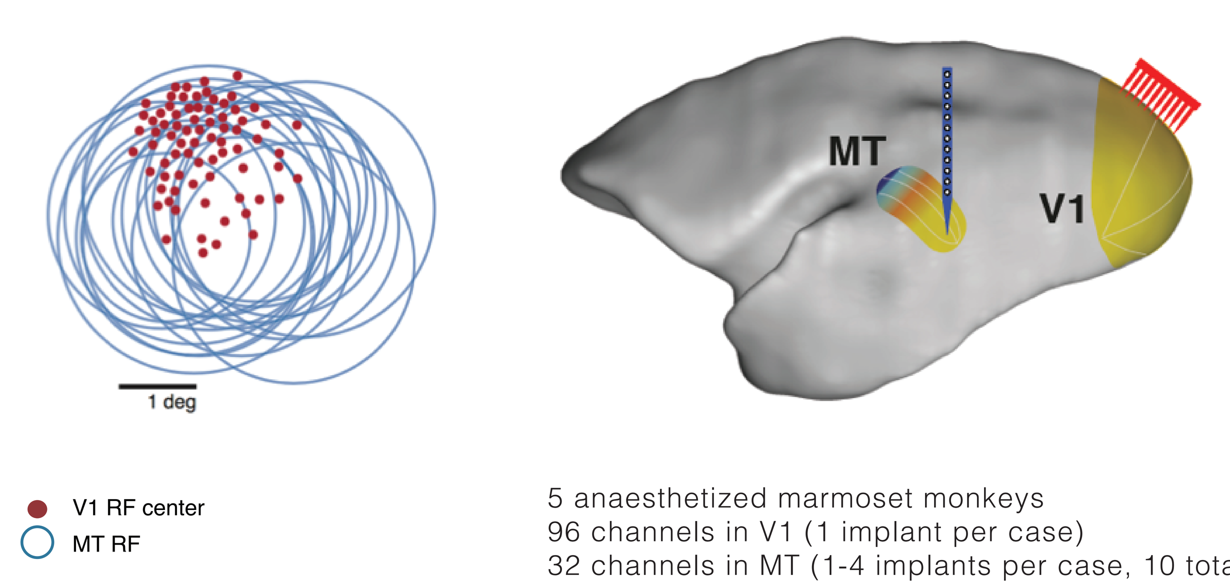
Sine wave gratings are narrow-band and contain no cross-scale phase information.

Square wave gratings are broad band and are phase aligned across scales.

Phase-randomised square wave gratings are broad band, but phases are scrambled cross-scale.

2. Population electrophysiology

Preparation



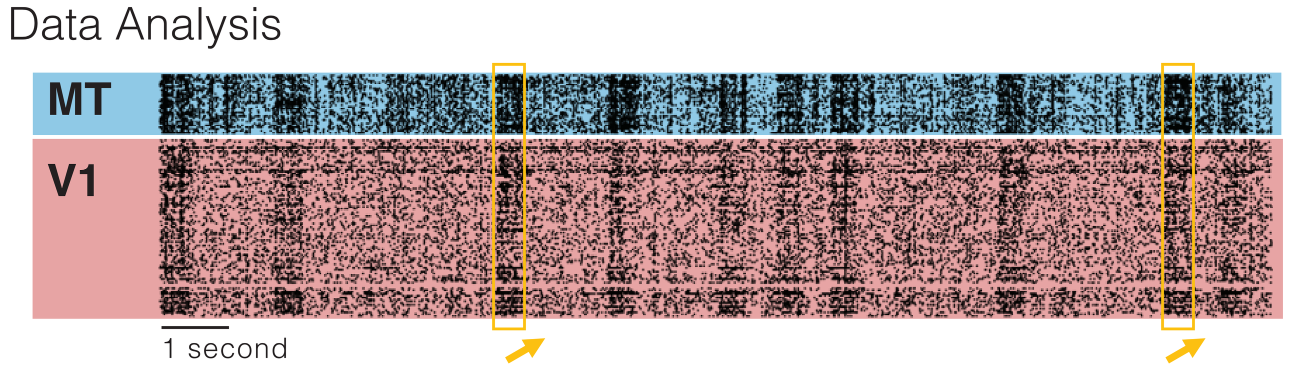
5 anaesthetized marmoset monkeys
96 channels in V1 (1 implant per case)
32 channels in MT (1-4 implants per case, 10 total)

Visual Stimulation

12 directions x 3 stimulus types
500 ms move
500 ms blank gray

circular aperture covering all RFs
SF and TF chosen to best evoke activity across all units
Receptive fields mapped at 0.5° resolution

Data Analysis



Spike counts Z-scored within a rolling 10s window
Independently for each direction and structure
Z-score distributions were matched across stimulus types

Correlations were calculated between neuron pairs that were visually responsive to any stimulus type.

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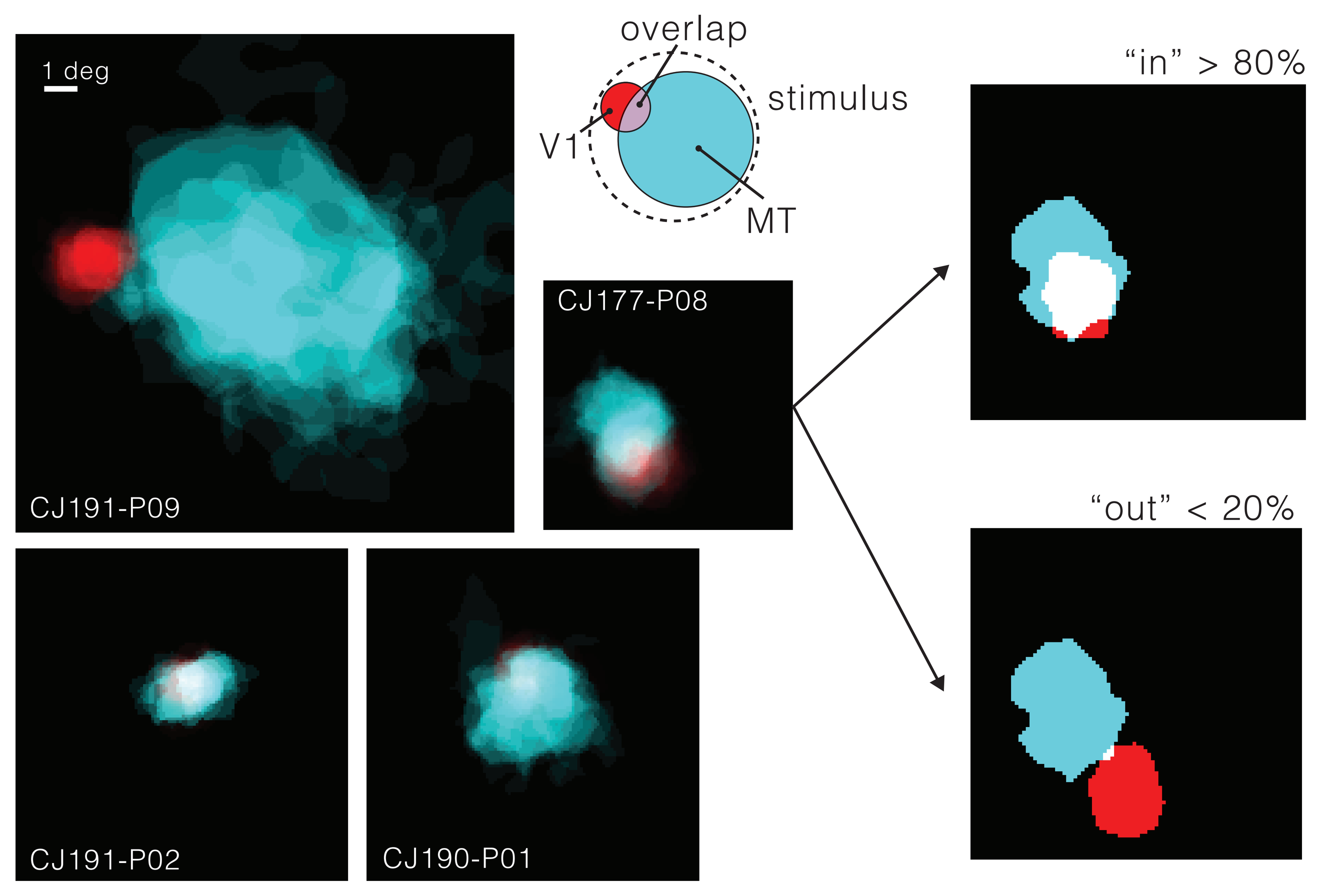
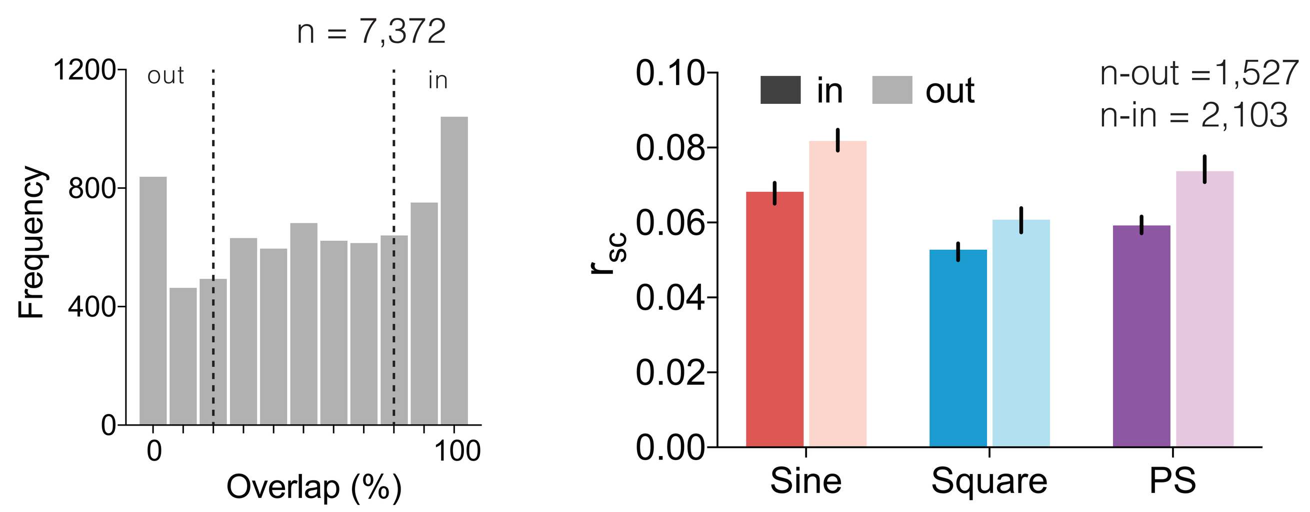
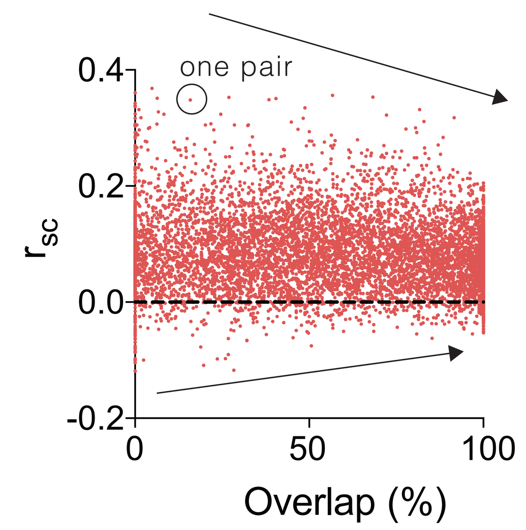
SPATIAL SELECTIVITY



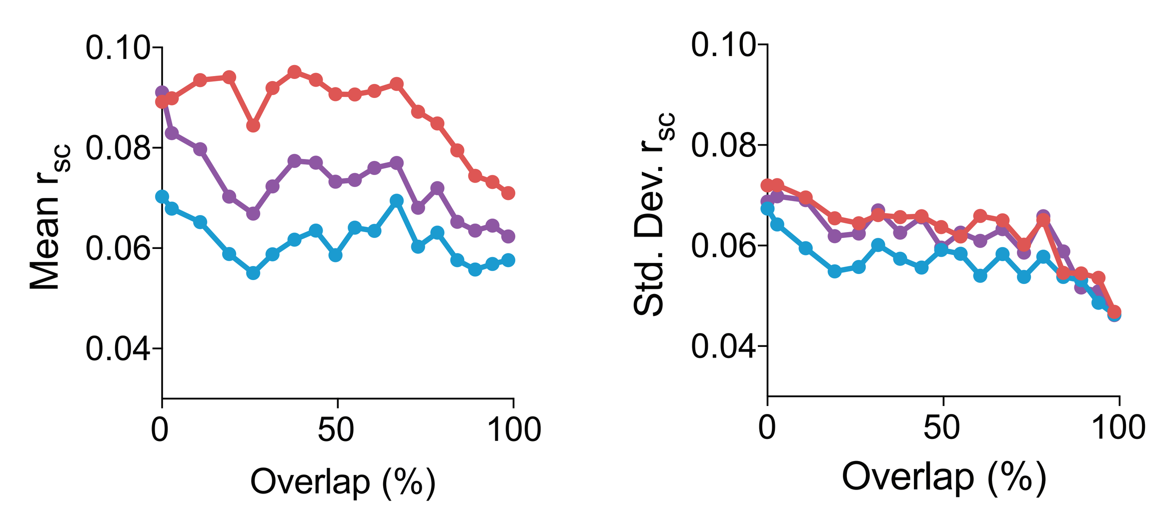


Between V1 and MT, correlations are **~20% lower** when receptive fields are overlapping for all stimulus types.



Shared variability is reduced overall as RF overlap increases

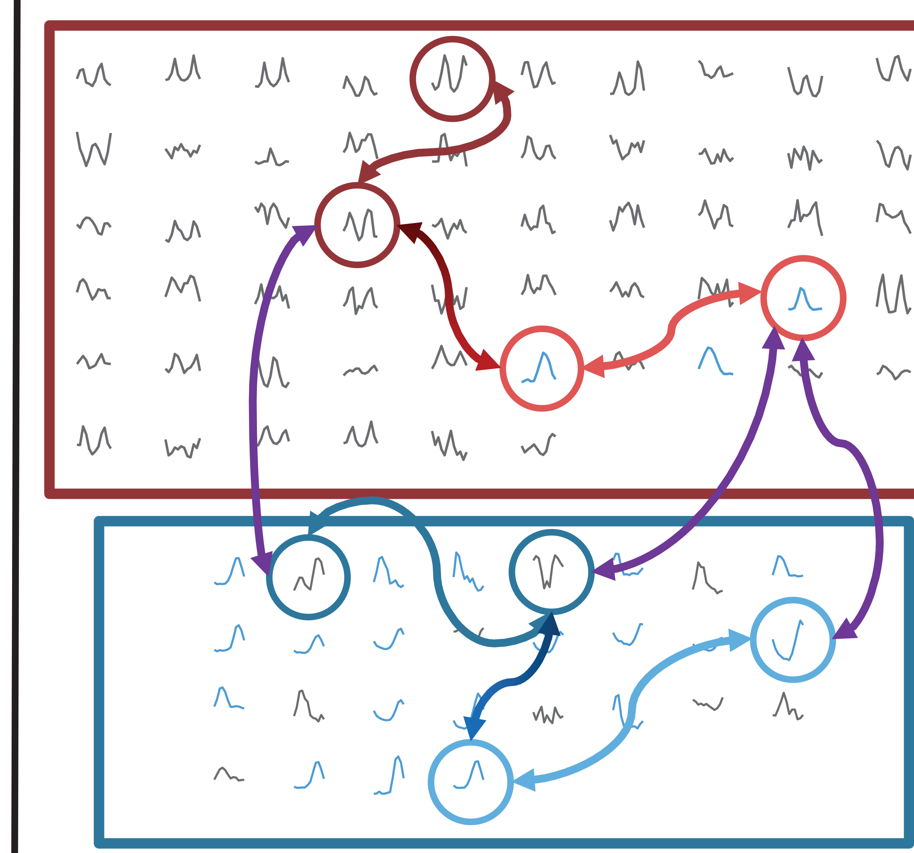
Population level variability also decreases with RF overlap increase.



Variability of the distribution of correlations decreases only when receptive field overlap becomes substantial.

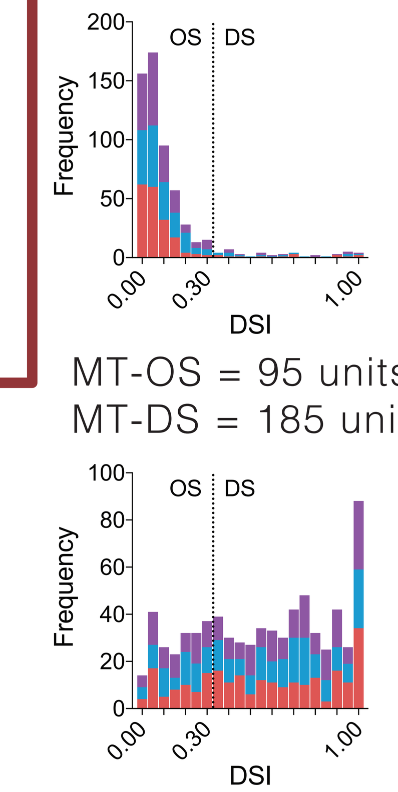
V1 neurons share lower correlated variability with the MT neurons whose receptive fields they overlap with. Furthermore, pairs with larger overlap tend to converge to a tighter distribution of correlations across the population.

DIRECTION SELECTIVITY

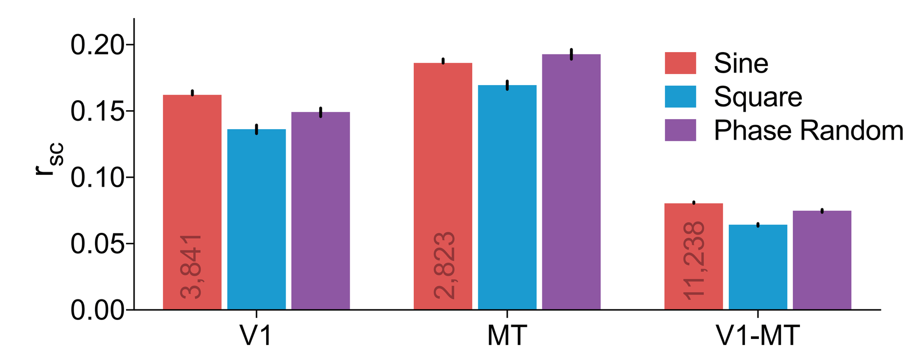


V1-OS = 178 units
V1-DS = 18 units

MT-OS = 95 units
MT-DS = 185 units



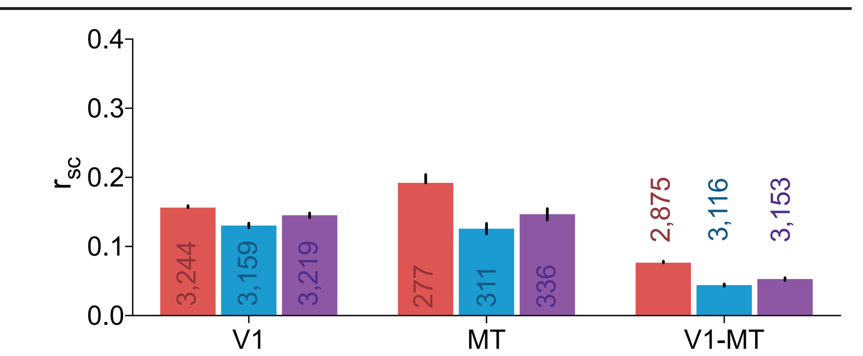
Correlated variability (rsc) is lower between areas than within areas.



Stimulus structure modulates correlated variability.

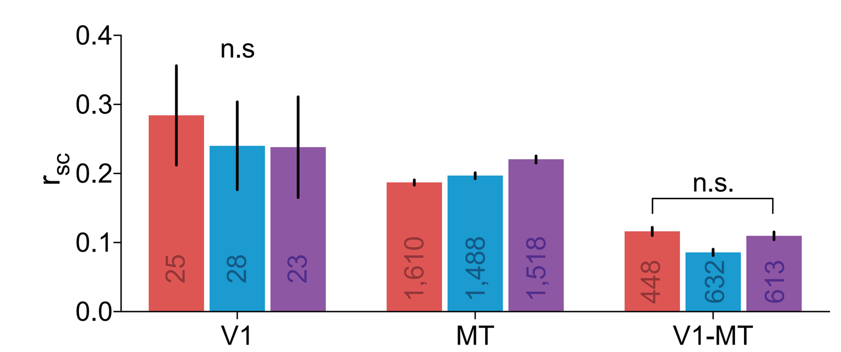
OS Networks

In orientation selective networks, structure reduces correlations in both MT, V1, and between them.



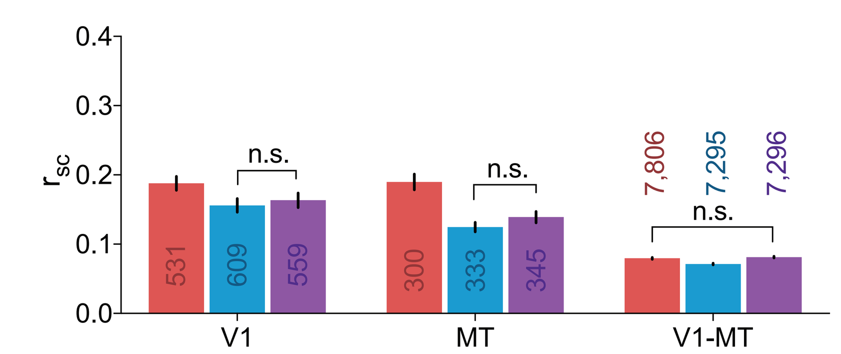
DS Networks

In direction selective networks, there are higher correlations overall, and no role for bandwidth in reducing correlations in MT.



OS-DS Networks

In mixed networks, phase alignment does not affect correlations.

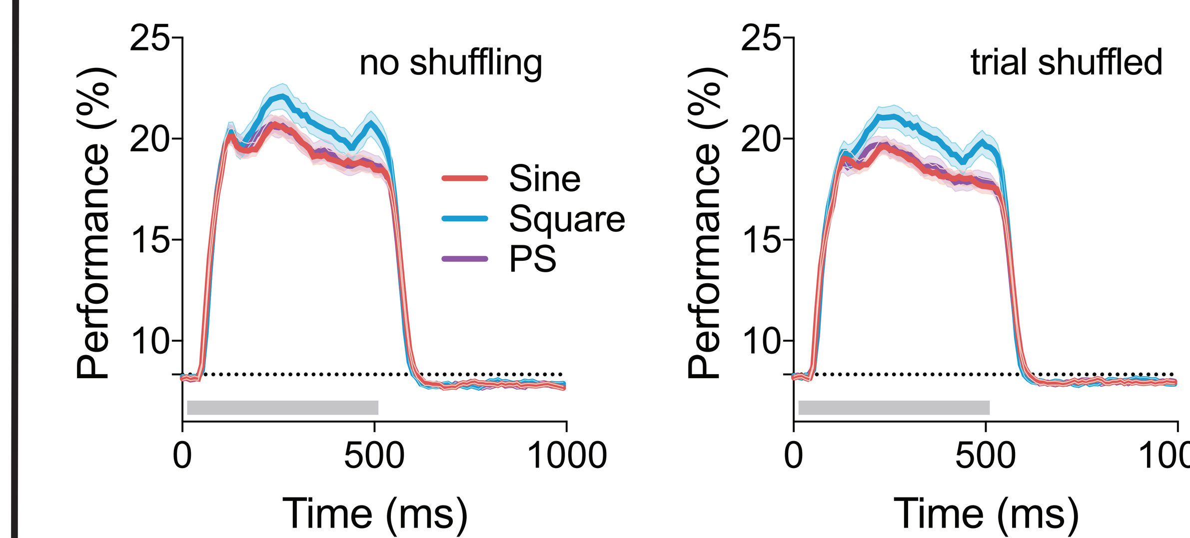


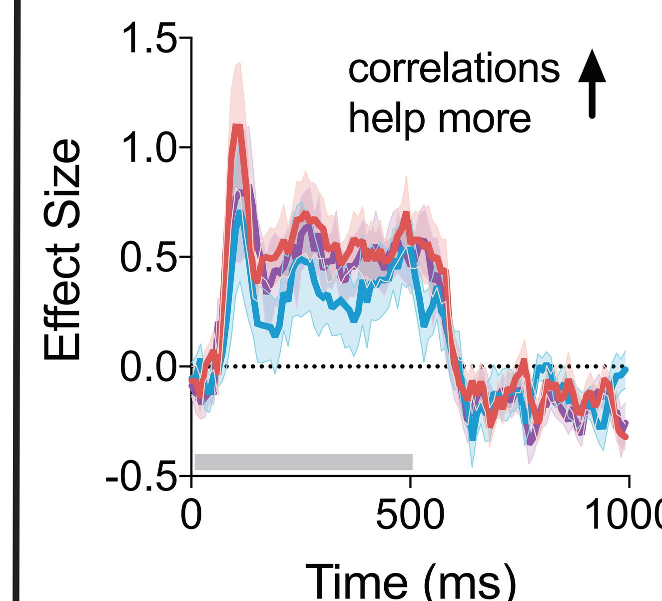
Noise correlations within and between V1 and MT are different for different sub-networks of neurons. In V1, and OS MT cells, bandwidth and structure reduce correlations, but DS MT cells are more stimulus invariant.

DIRECTION CODING IN MT

Decode simultaneously recorded MT populations in order to assess representation.

Compare to trial-shuffled decoding to isolate the contribution of correlated variability to the representation.





At each time point, measure the effect of trial shuffling with Cohen's *d*.

Correlations help decoding, and help more for those stimuli where overall decoding is worse.

Although stimulus structure impacts correlated variability, and improves decoding performance, the changes in noise correlations are not the mechanism by which these improvements are observed.

CONCLUSIONS

Population heterogeneity matters, because different subpopulations are influenced differently by external factors.

In V1, noise correlations are more sensitive to stimulus structure than in MT. This could result from normalisation pools specific for phase and orientation, but spanning many spatial frequencies.

Different regimes for local and global spatial processing may explain the lower, less variable between-area noise correlations in overlapping receptive fields.