Stimulus statistics restructure correlated variability within and between visual areas

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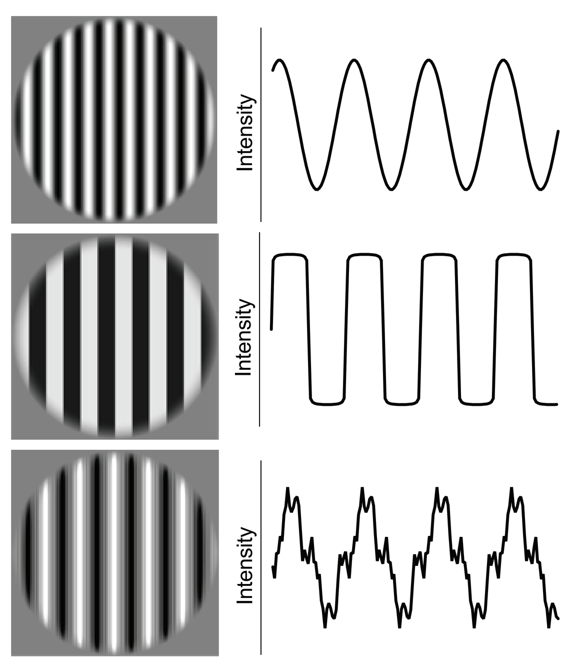
Many neurons in the primary visual cortex (V1) project to the middle temporal area (MT). In V1, motion representations are tightly coupled to the physical properties of the stimulus. In MT, a more robust, stimulus invariant, representation of motion direction is computed.

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 narrowband and contain no cross-scale phase information.

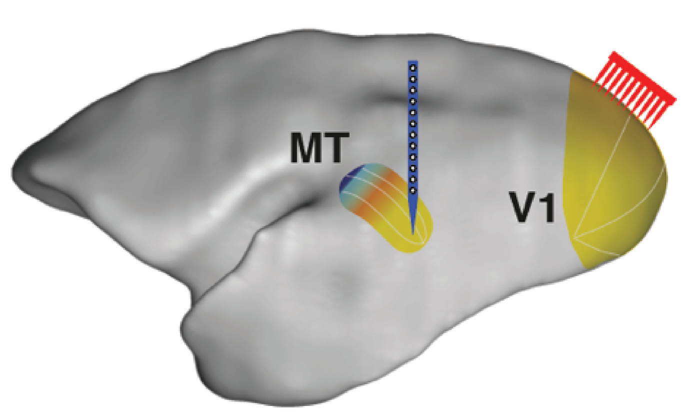
Square wave gratings are broad band and are phase aligned across scales.

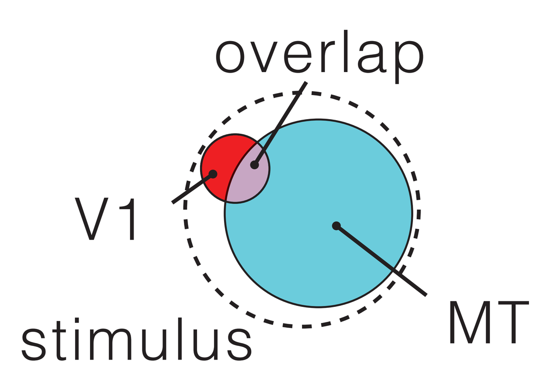
Phase-randomised square wave gratings are broad band, but phases are scrambled cross-scale.

Stimuli drifted in one of 12 directions for 500 ms, and were followed by 500 ms of blank screen.

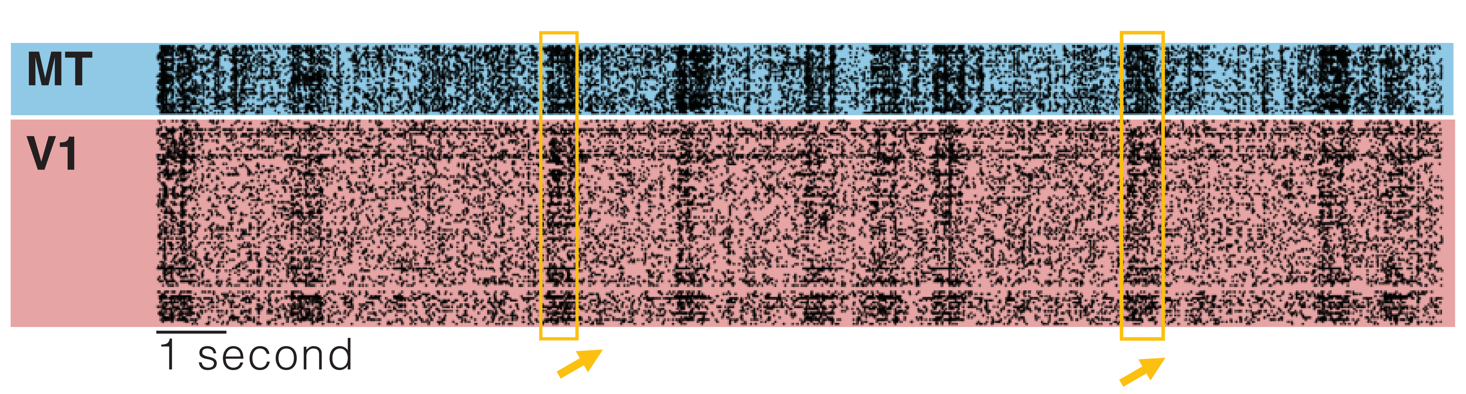
2. Population electrophysiology

Preparation





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



Spike counts Z-scored within a rolling 10s window
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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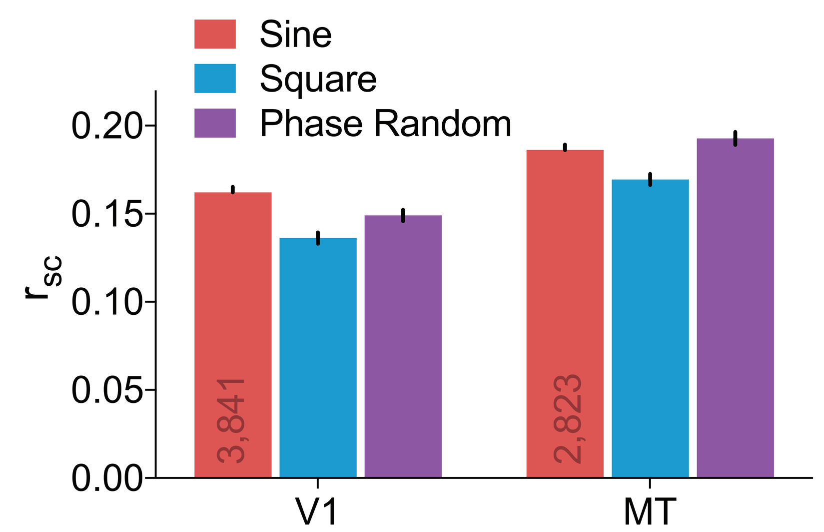
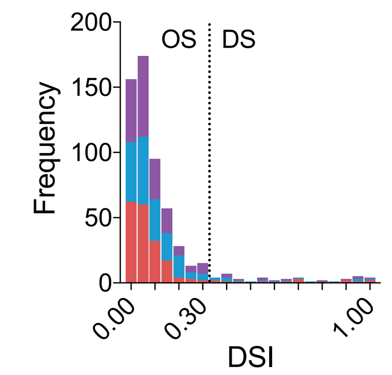
WITHIN AREA CORRELATIONS: V1 AND MT

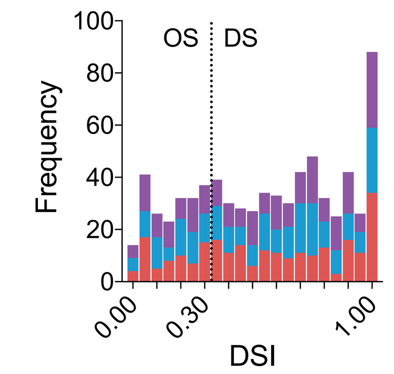


Within V1 and MT, stimulus bandwidth and structure modulates the strength of correlated noise (rsc).

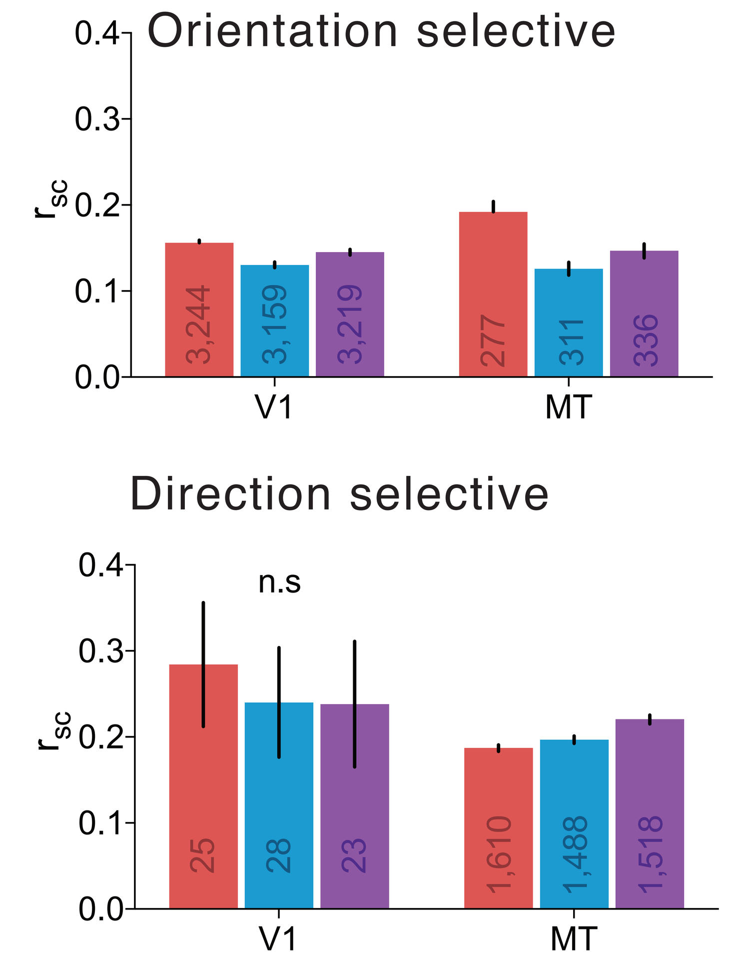
Direction selectivity propagates from V1 to MT, so we separated pairs based on selectivity.



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



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



SUMMARY

Stimulus structure changes the amount of correlated noise between pairs of neurons.

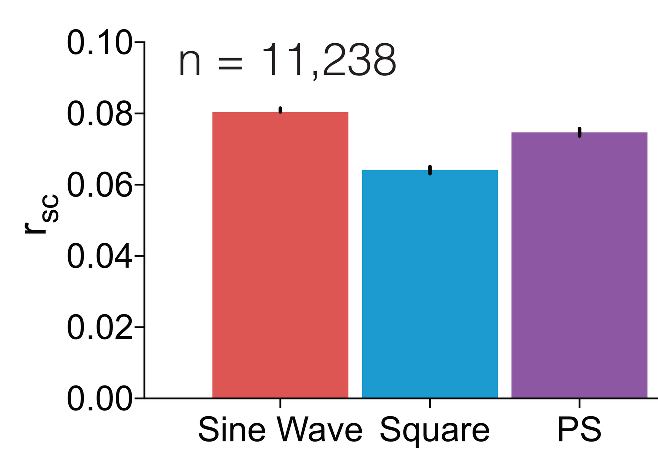
More naturalistic stimuli produce lower rates of noise correlation, possibly because larger and more specialised normalisation pools are recruited.

Correlations in sub-networks of neurons based on functional properties vary in **magnitude** and the **qualitative nature** of their stimulus dependence.

Qualitatively, correlations between units in MT and V1 exhibit the same dependence on stimulus and functional sub-network

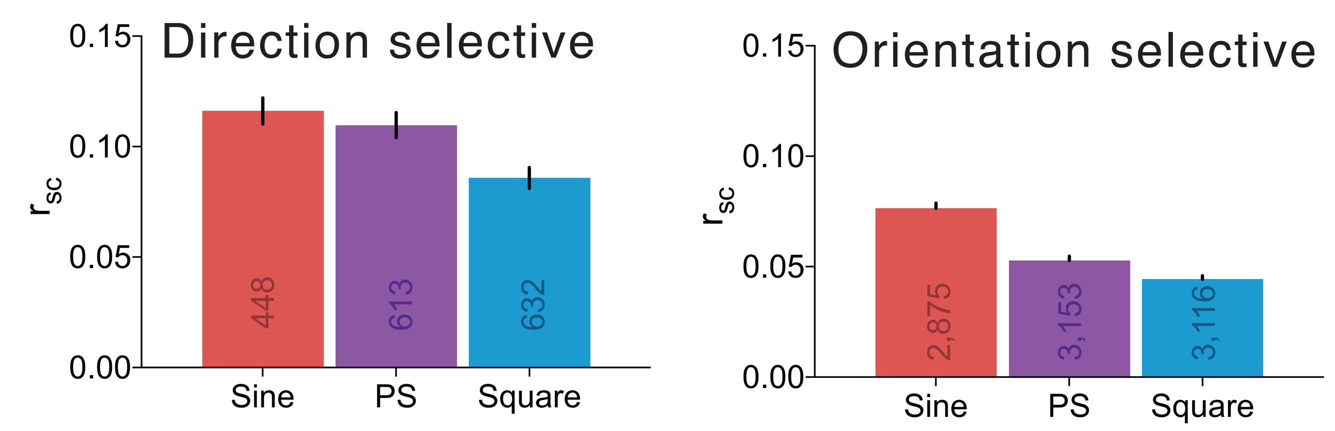
INTER-AREA CORRELATIONS: V1 TO MT

Inter-area correlations depend on stimulus structure



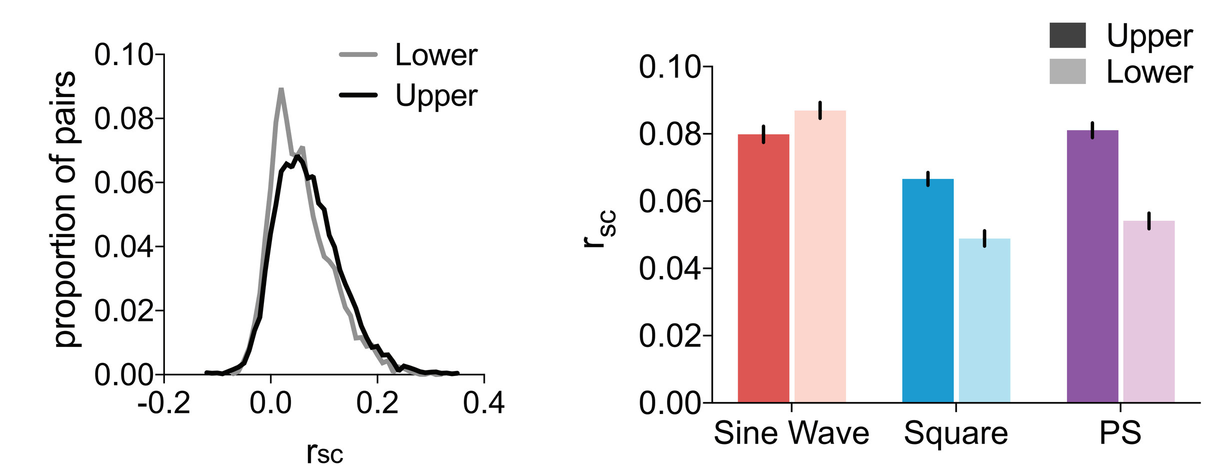
Correlated noise is lower between areas than within areas, but is affected by structure in the same way

Inter-area correlations depend on direction tuning



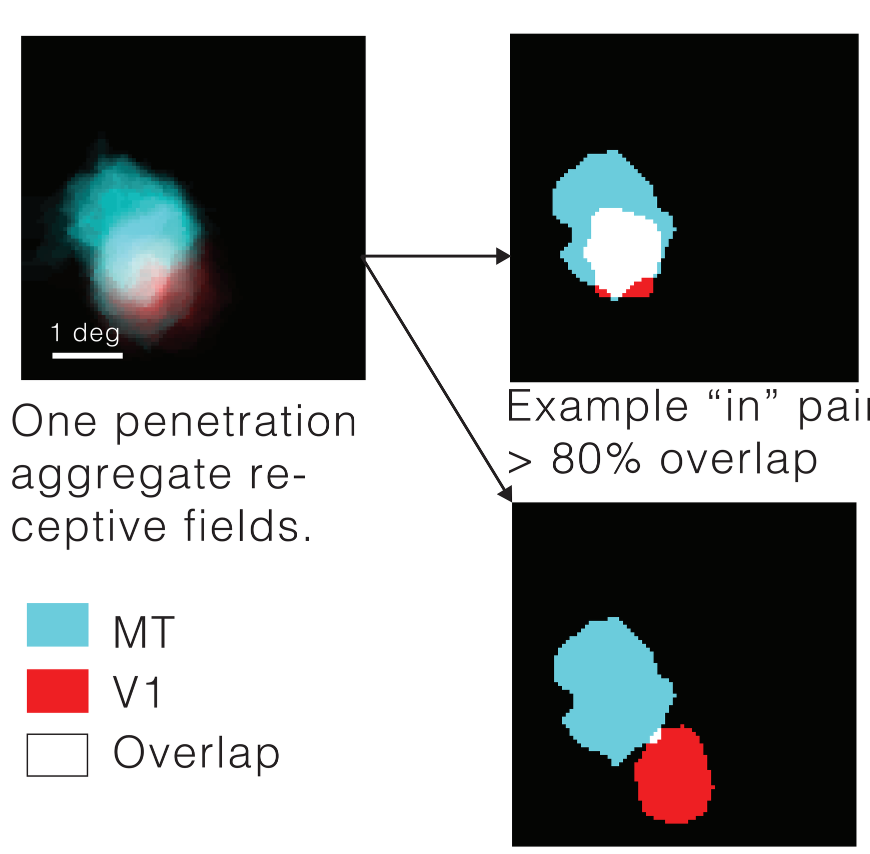
Correlations are higher when both members of a pair are direction selective than when both are orientation selective.

The effect of stimulus structure on correlations depends on MT layer



Correlations are higher in the upper layers of MT, but are more stucture-dependent in the lower layers.

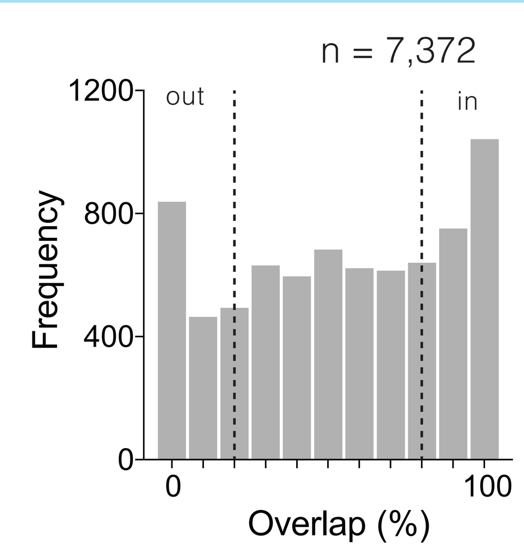
Inter-area correlations depend on receptive-field overlap

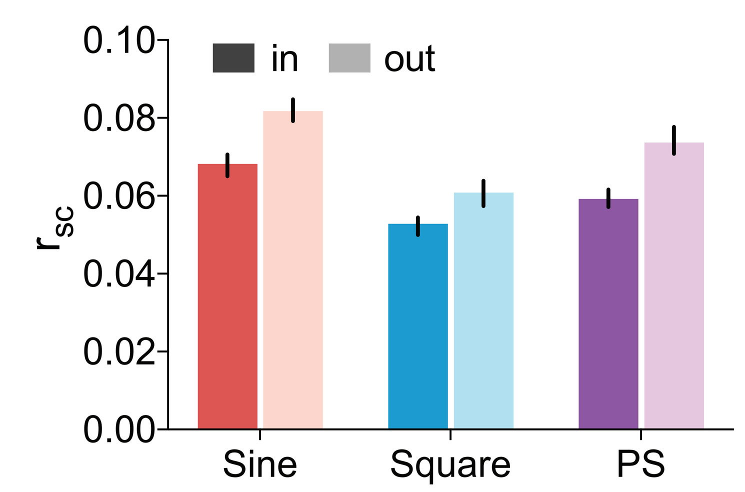


One penetration aggregate receptive fields.

Example “in” pair > 80% overlap

Example “out” pair < 20% overlap





The effect of stimulus statistics does not interact with receptive field overlap.

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

SUMMARY

Properties that are known to influence spike-count correlations interact with the effect of stimulus structure in different ways.

Correlation structure between V1 and MT appears not to reflect the pattern of correlations in either area individually.

The functional sub-network under consideration has a substantial effect on what spike-count correlations are observed and how they are impacted by experimental manipulations.