

# Representations of Multi-Feature Selectivity

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Many neurons involved in sensory processing show preferences for certain features in the sensory input. For example, cells in the primary visual cortex (V1) have long been known to show preferences for locally oriented bars in the visual field. Experimental evidence has indicated that intracortical connectivity may play an important role in orientation selectivity tuning [1]. Recurrent mechanisms for orientation tuning have been analyzed using the so-called *ring model*, in which interacting neuronal populations are indexed by a single angular variable representing their orientation preference. Through a combination of recurrent excitatory and inhibitory connectivity, the network can generate sharply-tuned, contrast-invariant tuning curves even in the case of weakly biased inputs from the lateral geniculate nucleus (LGN) [2, 3].

However, there are many aspects to orientation tuning in visual cortex that are not captured by the ring model. The ring model neither accounts for the two-dimensional distribution of orientation preference within a hypercolumn (organized around orientation pinwheels) nor the selectivity of V1 cells to other features of a visual scene such as spatial frequency, length, chromatic differences, or direction and velocity of motion. Recent efforts have been undertaken by Bressloff and Cowan [4] to extend the ring model to account for the orientation and frequency tuning properties of V1 cells. This is accomplished by way of a *spherical model* of a cortical hypercolumn. In this model, the orientation and frequency preferences of a cell correspond to the angular coordinates on a sphere. The poles of the sphere correspond to orientation pinwheels, which are associated with high and low spatial frequency preferences respectively. (This is motivated by recent optical imaging data [5]). The spherical model has been successful in representing both the orientation and frequency tuning of V1 cells, as well as making predictions about the interactions of orientation and spatial frequency that would have been impossible in the ring model.

Just as the use of the ring model has not been limited to vision, neither are cells with multiple feature maps limited to visual cortex. Neurons in rodent orbitofrontal cortex have been shown to have firing patterns that depend not only on spatial location but also to be odor specific [6]. Uses of the ring model outside of vision have included working memory in the pre-frontal cortex, and in particular, analysis of the robustness and drift of persistent network activity [7].

Here we discuss different topologies for the representation of multiple features. The topology chosen to represent multiple features depends on the features themselves. In the

example of the spherical model [4], there is one periodic feature (orientation) and one non-periodic feature (spatial frequency) organized around a pair of pinwheels (for each ocular dominance column within a hypercolumn). This suggests a spherical rather than a cylindrical topology.

Other topologies such as the cylindrical may still be important to consider for multi-feature processing. In the case of rodent orbitofrontal cortex, spatial position is a continuous variable that can be either periodic (e.g. rat running around a circular track) or non-periodic (e.g. rat running on a linear track). Discrete correlates, such as odors, may be best considered as ordered quantities leading to representational topologies such as the cylinder (periodic continuous correlate) or the plain (non-periodic continuous correlate). On the other hand, if a cell represents two features that are both periodic then the representation is toroidal.

As different topologies may be important for the consideration of multi-feature (and multi-modal) processing in different areas of the brain, we explore how these topologies differ in the representation, encoding, and interdependency of multiple feature maps in these topologies. We study the robustness of network activity such as the formation of tuning curves and persistent network activity in these different topologies. As well, this gives a springboard for looking at the differences in rate based models and spiking neurons in different network topologies.

## References

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