Beyond the uniform coverage hypothesis: coding without a map, or with fluctuating maps

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Abstract

I will discuss here some recent results about how the activity generated by information about external stimuli is encoded, distributed and interpreted in the brain, and particularly in the primary visual cortex (V1) of mammals. Ample work, triggered by the celebrated work of Hubel and Wiesel, led to a fine understanding of the responses of V1 to stimuli in various species, particularly in mammals. Neurons in V1 are classically thought to encode spatial features of visual stimuli through simple population codes: cortical columns, transverse to the surface of the cortex, exhibit a preferred orientation and preferred spatial frequency that are invariant to other aspects of the visual stimulus. In various mammalian species, it was further shown that the stimuli associated with maximal firing rates are organized according to continuous maps with discrete singularities. A classical view, originating from the work of Hubel and Wiesel themselves and formalized by Swindale and collaborators in particular, suggests that the relative arrangements of these maps are optimized for uniform coverage, that is, a uniform representation of all combinations of visual attributes.

In this talk, I will revisit the coding paradigm and uniform coverage hypothesis based on new high-resolution optical imaging data. First, I will show that spatial frequency and orientation maps violate the uniform coverage hypothesis, and rather prove consistent with an hypothesis of exhaustivity and parsimony of representation. Moreover, I will show that both coding through variations in firing rates and invariance of maps do not apply to the representation of major features of stimulus motion, including stimulus direction and temporal frequency. Instead, in over half of V1, preferred direction changed with stimulus TF, revealing four distinct map motifs embedded within

V1's functional architecture, while preferred TF was mostly uniform across the cortical surface. Despite the lack of spatial modulation for the preferred TF map and the lack of invariance for the preferred direction map, I will show, using convolutional neural networks, that direction, TF and stimulus speed can be accurately decoded from V1 responses at all cortical locations. These findings suggest that subtle modulations of V1 activity may convey fine information about stimulus motion, pointing to a novel primary sensory encoding mechanism despite complex co-variation of responses to multiple attributes across V1 neurons.

This talk will cover work with many collaborators, including Jérôme Ribot, Steve Van Hooser, Daniel Bennequin and others.