Correlations between neurons and their relation to network function: insights from a simple measure of coding efficiency

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The responses of cortical neurons often covary across identical behavioral trials. The significance of these 'noise correlations' is not fully understood, but with respect to the information carried by mean firing rates, it is generally thought that they limit the accuracy with which a neural population encodes sensory information. To determine their actual impact, however, two things need to be known: the complete correlation structure across the population, and the mechanism (ie., the computations) by which neuronal activity is read out downstream. The latter point means that the correlations within a population may or may not be relevant, depending on the way neuronal responses are combined by subsequent structures. I will discuss the case in which such downstream combinations are linear. In this situation, a simple measure of coding efficiency that does not depend on any particular task or downstream function can be derived. This quantity, the linear approximation error, has several attractive properties: (1) it depends only on the second order statistics of the neuronal responses, so although it is easy to compute, it does take the noise correlations into account, (2) it varies between 0 and 1, and (3) its magnitude has an intuitive interpretation in terms of the accuracy with which information can be extracted from the population using a simple method ('simple' meaning linear). Because this measure is concened with signals that can be read out easily (i.e., through linear operations), it provides an indication of how explicit a neural code is. This measure will be used to characterize the efficacy of several types of population responses generated synthetically in a computer and having various correlation structures. Two results stand out from this analysis. First, although it is much simpler to compute, the linear approximation error typically ranks the variety of encoding schemes in a way that is qualitatively similar to Shannon's mutual information. This is not the case, however, when nonlinear readout methods are necessary. Second, the precise effect of noise correlations depends on their distribution across the population and on the tuning properties of the neurons, as suggested earlier, but their impact seems to be generally modest.