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Diverse Neuronal Responses Produce Low Dimensional Variability in Cortical Circuits

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I will discuss two distinct features of neuronal response. First, neuronal activity is very diverse -- in response to a specific stimulus or behavior some neurons emit many action potentials, and many others are relatively silent. Second, trial-to-trial fluctuations of neuronal response occupy a low dimensional space, owing to significant correlations between the joint activity of neurons within a population. We will link these two aspects of neural representation using a recurrent circuit model and derive the following relation: the more diverse the distribution of trial-averaged responses, the lower the effective dimension of population trial-to-trial covariability. This surprising prediction is tested and validated using multiple population datasets from numerous brain areas in mice, non-human primates, and in the motor cortex of human subjects. We present a simple theory whereby a more heterogeneous neuronal code leads to better fine discrimination performance through a lowering of the dimension of population covariability. In line with this result, we show that neural populations across the brain exhibit both more diverse mean responses and lower-dimensional fluctuations when the brain is in more heightened states of information processing. In sum, we present a key organizational principle of neural population response that is widely observed across the nervous system and acts to synergistically improve population representation.