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Visualization and classification of neural ensemble encoding patterns by subspace analysis methods

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Recent advances in multi-electrode recording techniques in freely-behaving animals allow the simultaneous monitoring of large-scale neural activity patterns. Analysis of such complex high-dimensional datasets presents challenges as the efficiency of traditional statistical is greatly decreased when the numbers of dimensions becomes very large. To address this issue, we employed a series of projection methods, such as Multiple Discriminant Analysis (MDA), Principal Components Analysis (PCA) and Artificial Neural Networks (ANN), and compared them with non-projection multivariate statistical methods such as Multivariate Gaussian Distributions (MGD). We use two simulated data sets of monkey cortical activity during face perception or arm movements, and recorded data sets from mouse hippocampus during exposure to startling episodic events to illustrate how different network-level ensemble patterns can be projected and classified in low-dimensional encoding subspaces. We investigate how over-fitting of training data sets, which can occur when due to experimental constraints the number of training data points is much smaller than the number of recorded units, can be prevented by using regularization methods. Evaluation of discrimination accuracy of these methods indicates that the projection methods outperform the multivariate methods that operate in the original large-dimensional parameter space (MDA > PCA > ANN > MGD). We also show that the computations implemented by the projection methods reflect the hierarchical features implemented in the simulated neural data sets. We conclude that subspace projection methods, in particular MDA and PCA, are effective not only in extracting essential features from complex data sets, but also in allowing the visualization of the neural network-level encoding patterns and their temporal dynamics.