Measures of Neural Discrimination

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In sensory systems, neural discrimination measures the ability of single or ensemble of neurons to classify stimulus features. Measuring neural discrimination is useful because it provides a model free assessment of the neural coding occurring in a given processing stage. Neural discrimination measures can thus be used to investigate the nature of code (eg. rate vs temporal code), to validate models (eg. linear vs. non-linear) and to assess the relevant stimulus space (eg. natural vs synthetic; phoneme vs. syllable). Neural discrimination for ensembles of neurons can also be compared to neural discrimination for single neurons thus measuring the degree of redundancy or synergy in ensemble codes. Finally, neural discrimination can be assessed in different processing stages to investigate changes in the neural representation.

In this study, we compared four alternative measures of neural discrimination each with successively fewer assumptions. We first calculated the within-d' statistic: the difference in firing rates normalized by their standard deviation for different pairs of stimuli. This measure assumes that the information is represented in the total number of spikes fired and that these are normally distributed. Second, we used an ideal observer (IO) approach and calculated the percentage of successful stimulus identifications [1]. The IO method we used calculated the similarity between template spike trains and observed spike trains and, in this manner, took spike timing information into account. However, just as for the d' measure, it assumes that the scale we used to define the elements of the stimulus ensemble was the relevant one. Finally, we used two alternative methods to estimate the Mutual Information (MI): one based on an inhomogenous gamma model [2] and one based on the instantaneous firing rate only.

We tested the validity of these four measures of neural discrimination by estimating the information in single neurons in the avian auditory forebrain while processing song. We found that the gamma information and the IO measure showed a very high degree of concordance. The rate information could also provide a good approximation but only when it was estimated for a particular time window of ~ 40 ms. The d' measure fell short in that it correlated poorly with all the other measures. Our study suggests that IO measures and rate information could also be used to estimate ensemble information as long as the relevant time scale is assessed independently.

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References