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Nonlinear dynamical analysis of firing patterns of globus pallidus neurons

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We recorded in slices from rat globus pallidus neurons using cell attached, whole cell and perforated patch clamp techniques, and employed dynamical systems methods to address the basis of their complex spike time patterns. The fraction of interspike intervals (ISIs) below a certain level are compared to a similar fraction from a Gaussian distribution to quantitatively compare the shape of our ISI distributions to a Gaussian (q-q plot). A linear curve in the q-q plot indicates that the ISI distribution is Gaussian. Many of our ISI distributions drawn from samples recorded for long durations (1 hr) deviated significantly from such a linear relationship. Some of the shorter time samples (e.g. 100 consecutive ISIs) derived from the longer recordings showed more agreement with Gaussian distribution. This indicates that these distributions are influenced by spontaneous changes in firing rate. However, others still deviated significantly showing long and slow decaying tail regions. These deviations from a Gaussian distribution cannot be accounted for by a rate nonstationarity. Despite the complexity of the firing patterns, the ISIs show strong spike time autocorrelations. We computed the fraction of closely spaced ISI pairs as a function of their separation. This function increased linearly with their separation as expected for a random process (i.e. their correlation dimension is 1). This suggests that the spike time jitter intrinsic to the globus pallidus neurons is either driven by membrane noise or due to high dimensionality of the underlying dynamics. In fact, when we time shifted each ISI array to construct a pseudo dimensional vector array (time-delay embedding), and computed its correlation dimension, we found that such a dimension increased with the pseudo vector dimension, indicating the high dimensionality of the underlying dynamics. These results suggest that the variability in spike intervals of spontaneously active GP cells is due to a stochastic process acting within the oscillatory mechanism.

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