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A model for the joint evaluation of burstiness and regularity in oscillatory spike trains

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Introduction

The ability of neurons to emit different firing patterns is considered relevant for neuronal information processing. In dopaminergic neurons, prominent patterns include highly regular pacemakers with separate spikes and stereotyped intervals, processes with repetitive bursts and partial regularity, and irregular spike trains with nonstationary properties. In order to model and quantify these processes and the variability of their patterns with respect to pharmacological and cellular properties, we aim to describe the two dimensions of burstiness and regularity in a single model framework.

Methods

We present a stochastic spike train model in which the degree of burstiness and the regularity of the oscillation are described independently and with two simple parameters. In this model, a background oscillation with independent and normally distributed intervals gives rise to Poissonian spike packets with a Gaussian firing intensity. The variability of inter-burst intervals and the average number of spikes in each burst indicate regularity and burstiness, respectively. These parameters can be estimated by fitting the model to the autocorrelograms. This allows to assign every spike train a position in the two-dimensional space described by regularity and burstiness and thus, to investigate the dependence of the firing patterns on different experimental conditions. Finally, burst detection in single spike trains is possible within the model because the parameter estimates determine the appropriate bandwidth that should be used for burst identification.

Results and Discussion

We applied the model to a sample data set obtained from dopaminergic substantia nigra and ventral tegmental area neurons recorded extracellularly in vivo and studied differences between the firing activity of dopaminergic neurons in wildtype and K-ATP channel knock-out mice. The model is able to represent a variety of discharge patterns and to describe changes induced pharmacologically. It provides a simple and objective classification scheme for the observed spike trains into pacemaker, irregular and bursty processes. In addition to the simple classification, changes in the parameters can be studied quantitatively, also including the properties related to bursting behavior. Interestingly, the proposed algorithm for burst detection may be applicable also to spike trains with nonstationary firing rates if the remaining parameters are unaffected. Thus, the proposed model and its burst detection algorithm can be useful for the description and investigation of neuronal firing patterns and their variability with cellular and experimental conditions.