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Synaptic transmission of spike trains with arbitrary interspike intervals

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Short-term synaptic depression, caused by depletion of releasable neurotransmitter vesicles, modulates the strength of neuronal connections in an activity-dependent manner [1,2]. Quantifying the statistics of this form of synaptic transmission requires the development of stochastic models linking probabilistic neurotransmitter release with the spike-train statistics of the presynaptic population [3,4]. A common approach has been to model the presynaptic spike train as either regular or a memory-less Poisson process [5] - few analytical results are available that describe the behaviour of a depressing synapse when the afferent spike train has more complex, temporally correlated statistics.

Recently, we have derived a series of results that allow for the fraction of occupied release sites and the neurotransmitter release probability to be calculated for a presynaptic spike train with arbitrary interspike interval (ISI) statistics. The results take a particularly compact form when the presynaptic spike times are generated by a renewal process, i.e. when the ISIs are independent. This encompasses a broad range of models that are currently used for circuit and network analyses, including the class of integrate-and-fire models. Our approach also allows for the postsynaptic voltage mean and variance to be calculated, which in turn allows for an approximation of the firing rate of a neuron driven by depressing synapses from non-Poissonian presynaptic neurons (Figure 1).

These results will allow for the incorporation of more complex and physiologically relevant firing patterns

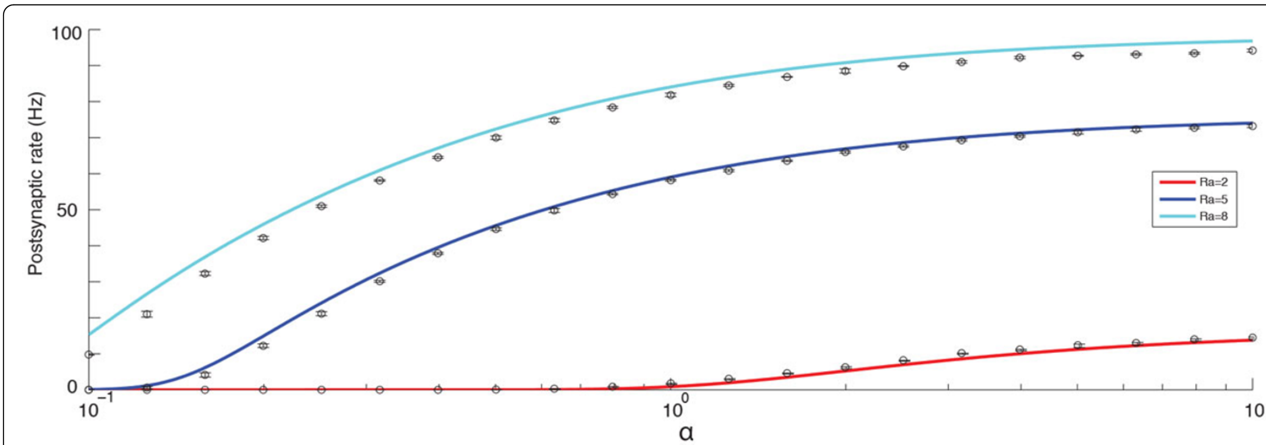

Figure 1 Predictions of postsynaptic firing rates as a function of the regularity of the renewal process governing presynaptic firing. Presynaptic interspike intervals are independently identically gamma distributed with shape parameter α (increasing α gives more regular firing) and mean $\mathbf{1/R_{\alpha}}$. Simulated rates are shown as circles with error bars. Analytic predictions are shown as solid lines based on exact forms for the postsynaptic voltage mean and variance.

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into future analytic studies of neuronal circuits and networks.

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