

POSTER PRESENTATION

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Optimal spike pattern v.s. noise separation by neurons equipped with STDP

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Using numerical simulations and analytical calculations, we have recently demonstrated that, thanks to the physiological learning mechanism referred to as Spike Timing-Dependent Plasticity (STDP), neurons can detect and learn repeating spike patterns, in an unsupervised manner, even when those patterns are embedded in noise[1-3] - a computationally difficult problem. Here, we show that the learning rule is optimal, in that it maximizes the response to the patterns, while minimizing the mean response to noise. Therefore, by thresholding the response, one can at the same time maximize the hit rate, and minimize the false alarm rate.

More formally, if one considers a linear neuron, with n excitatory afferents, with synaptic weights $w_1 \dots w_n$ in $0[1]$, and one input spike pattern, the goal is to find a set of synaptic weights that maximizes the neuron's response to the pattern, while minimizing the mean response to Poisson input noise. We first show that, to find the optimal set, one should convolve the input spike pattern with the excitatory postsynaptic potential (EPSP) response kernel, and select the highest resulting peaks. For each peak p , only a subset of the afferents n_p contributed significantly to the response. One should select the highest peak with minimal n_p , choose $w = 1$ for the contributing afferents, and $w = 0$ for all the others (in order to minimize the mean response to Poisson noise). Then, we investigate the conditions under which STDP indeed reaches this optimum, using analytical calculations with a linear inhomogeneous Poisson model[3,4], as well as simulations with both leaky-integrate-and-fire (LIF) and Poisson neurons.

Our results indicate that, in a number of cases, STDP indeed reaches this optimum, especially when coupled

with homeostatic mechanisms. In other words, when faced with one repeating pattern to learn, STDP tends to chose the best "signature" of this pattern, that is a time window with as many (nearly) coincident spikes as possible from as few afferents as possible, and concentrates weights on these afferents only, thereby minimizing the probability of strong responses due to fortuitous spike coincidences. When faced with multiple repeating patterns, the ones with best signatures tend to be learned in priority.

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References

1. Masquelier T, Guyonneau R, Thorpe SJ: Spike timing dependent plasticity finds the start of repeating patterns in continuous spike trains. *PLoS ONE* 2008, **3**:e1377.
2. Masquelier T, Guyonneau R, Thorpe SJ: Competitive STDP-Based Spike Pattern Learning. *Neural Comput* 2009, **21**:1259-1276.
3. Gilson M, Masquelier T, Hugues E: STDP allows fast rate-modulated coding with Poisson-like spike trains. *PLoS Comput Biol* 2011, **7**:e1002231.
4. Kempter R, Gerstner W, Van Hemmen JL: Hebbian learning and spiking neurons. *Phys Rev E* 1999, **59**:4498-4514.
5. Goodman D, Brette R: Brian: a simulator for spiking neural networks in python. *Front Neuroinformatics* 2008, **2**:5.

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