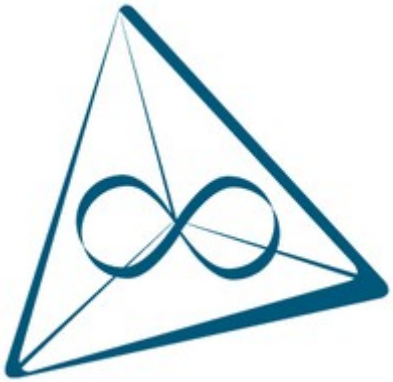
STDP leads to efficient coding of predictions

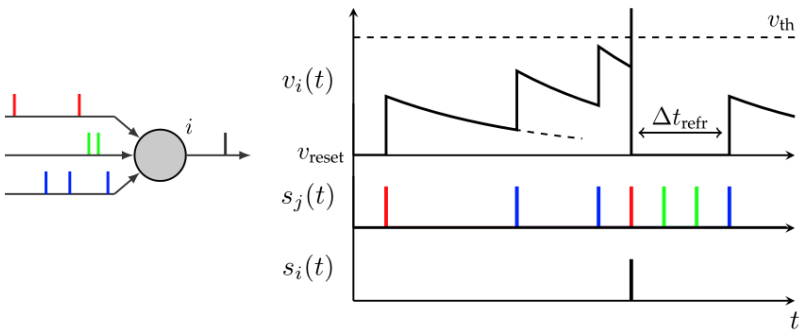
Pau Vilimelis Aceituno
Masud Ehsani
Jürgen Jost

MAX PLANCK SCHOOL of cognition



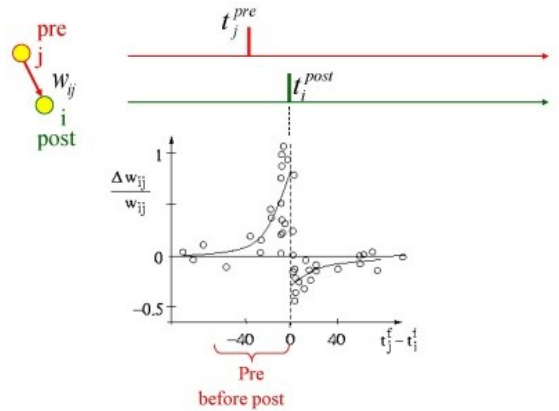
Models

- Leaky Integrate and Fire Neurons



Paredes-Vallés et al., *IEEE Trans. In Pattern Analysis and Machine Intelligence*

- Spike-Time Dependent Plasticity

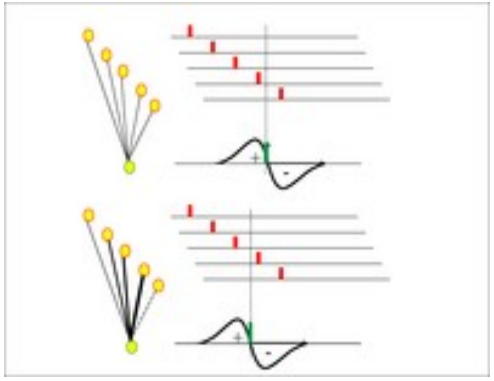


Söjöstrom & Gerstner, *Scholarpedia*

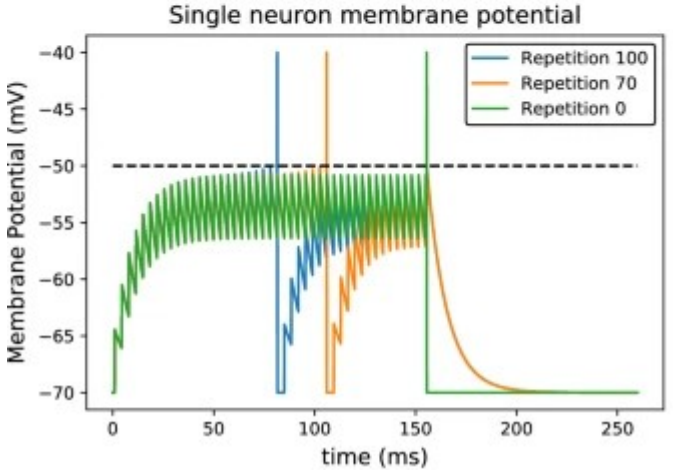
- Input Spike trains:
  - Few spikes per presynaptic synapse
  - Input time random, but fixed across repetitions
  - E/I, noise, multiple input spike trains

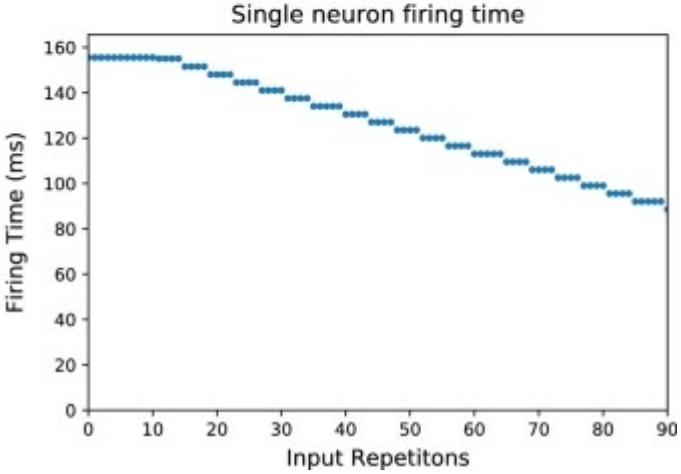
Spike evolution: Latency

- STDP reinforces inputs arriving *before* a postsynaptic spike, creating an *earlier* spike
- Observed in hipocampus (Mehta et al. *Neuron*)



Spike-Timing Dependent Plasticity, Söjöstrom & Gestner, *Scholarpedia*

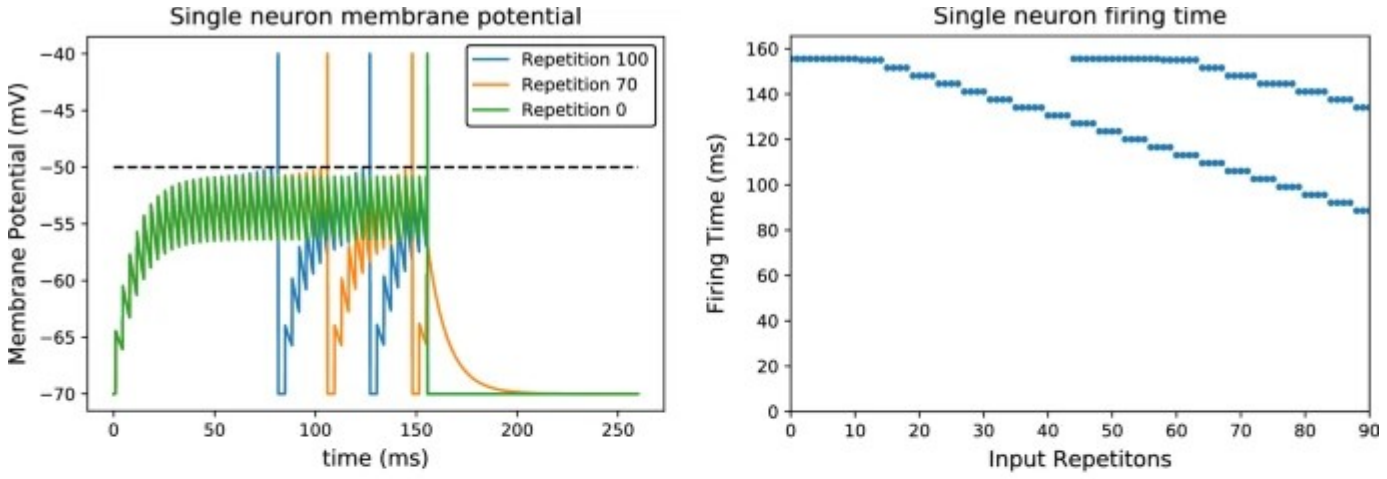




Spike evolution: proliferation

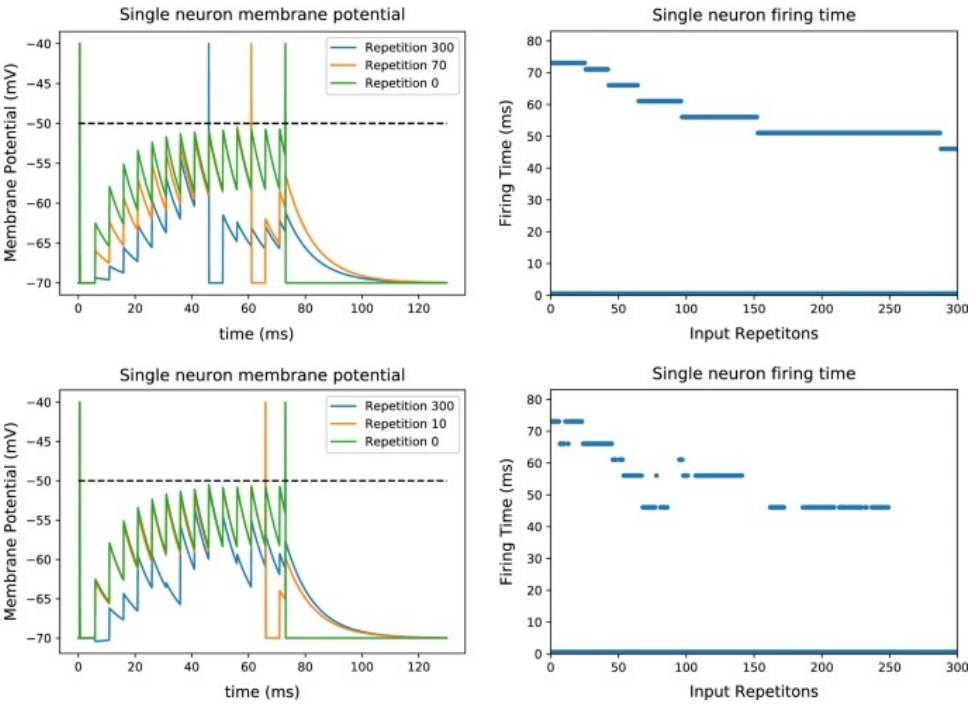
- If a spike moves forward in time without altering the inputs (antisymetric STDP), the original spike will reapear

  → presynaptic depression > presynaptic potentiation



Spike evolution: disappearance

- When two postsynaptic spikes are close in time the second one tends to disappear
- But only if there is some noise
- Similar to triplet rules

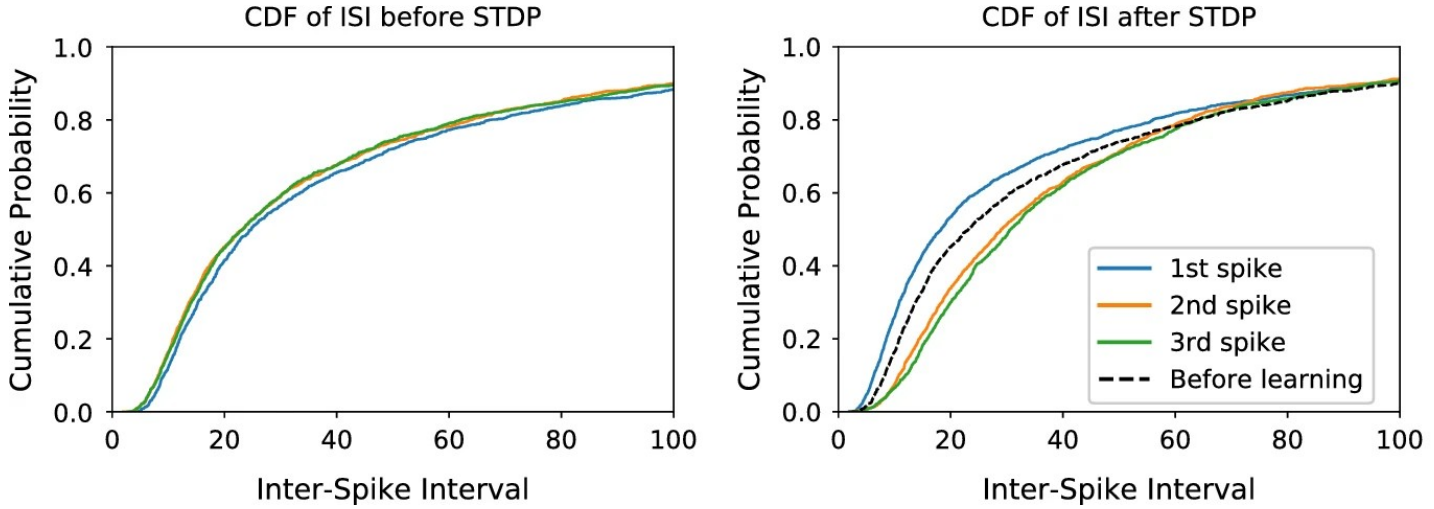


Spike Trains: technicalities

- All the phenomena assume that postsynaptic spikes evolve **independently** → Constraints on in/out rate
  - Depression/potentiation happen only from a single pre/post pair
  - Synapses with multiple spikes don’t overlap in time
- **Inhibitory/Excitatory balance** can be maintained
  - If the inhibitory plasticity fulfills specific conditions
- Multiple variants of plasticity yield same results
  - Triplet rules, multiple inhibitory variants, short-term plasticity...

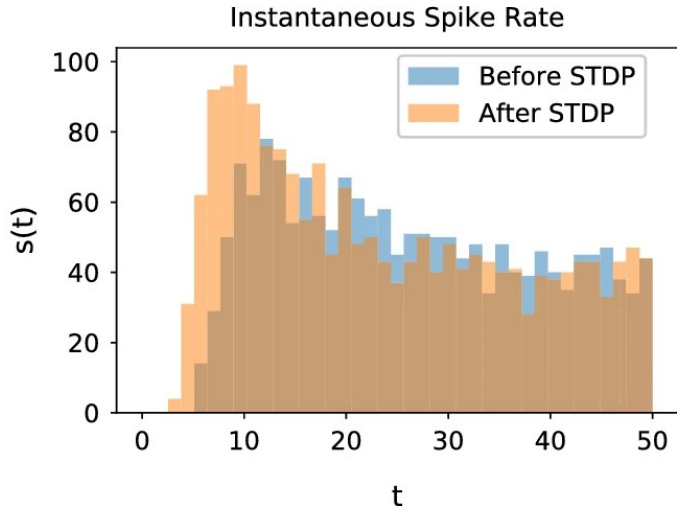
Spike train evolution I

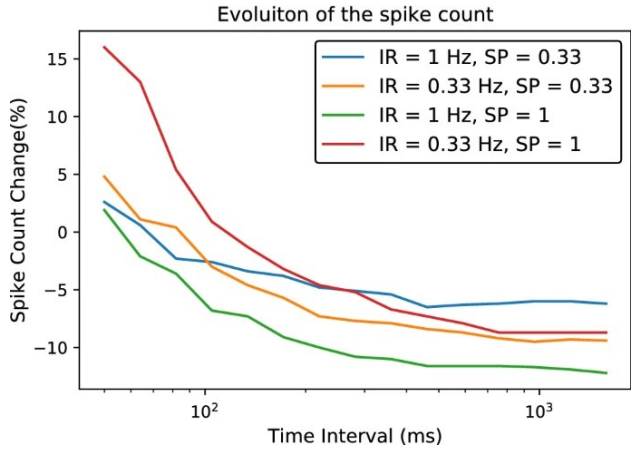
- Its a point process in time → Look at the CDF of the inter-spike interval
- First spike moves forward, later spikes spread apart



Spike train evolution

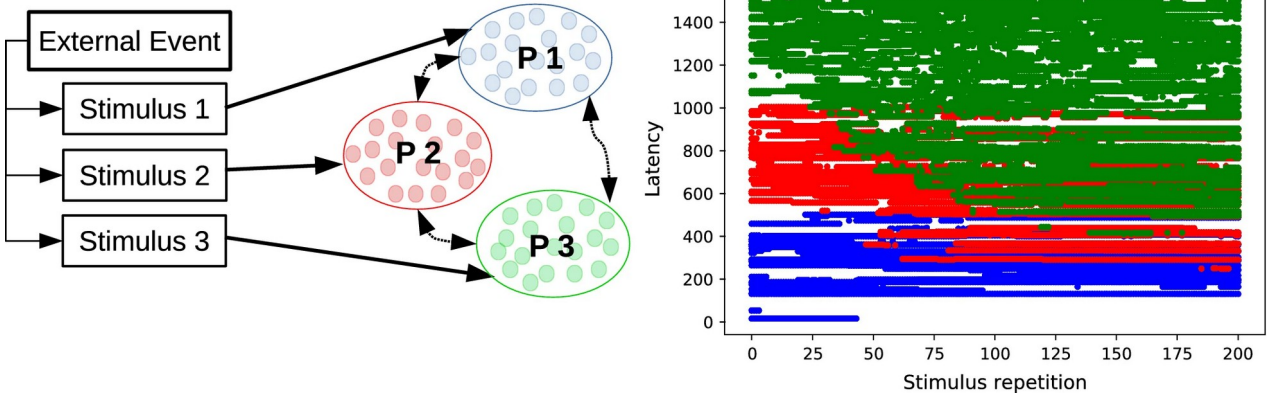
- Peak of spikes at the beginning of the spike train
- Total number of spikes decreases if the time interval is long and the input rate is high





Predictions

- Spikes happen earlier and earlier until they happen *before* the stimulus that they originally encoded



Conclusion & Next Steps

Summary

- Spikes move forward in time through STDP
- A peak of activity appears at stimulus onset
- But the total number of spikes is reduced
- Predictions emerge

Next Steps

- Study the efficiency of sequential multi-channel sparse codes
- Encoding predictions without predictive coding?
- Evolution of prediction?

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