MemSpikingTM



Demonstration of Sequence Learning on a Memristive Array

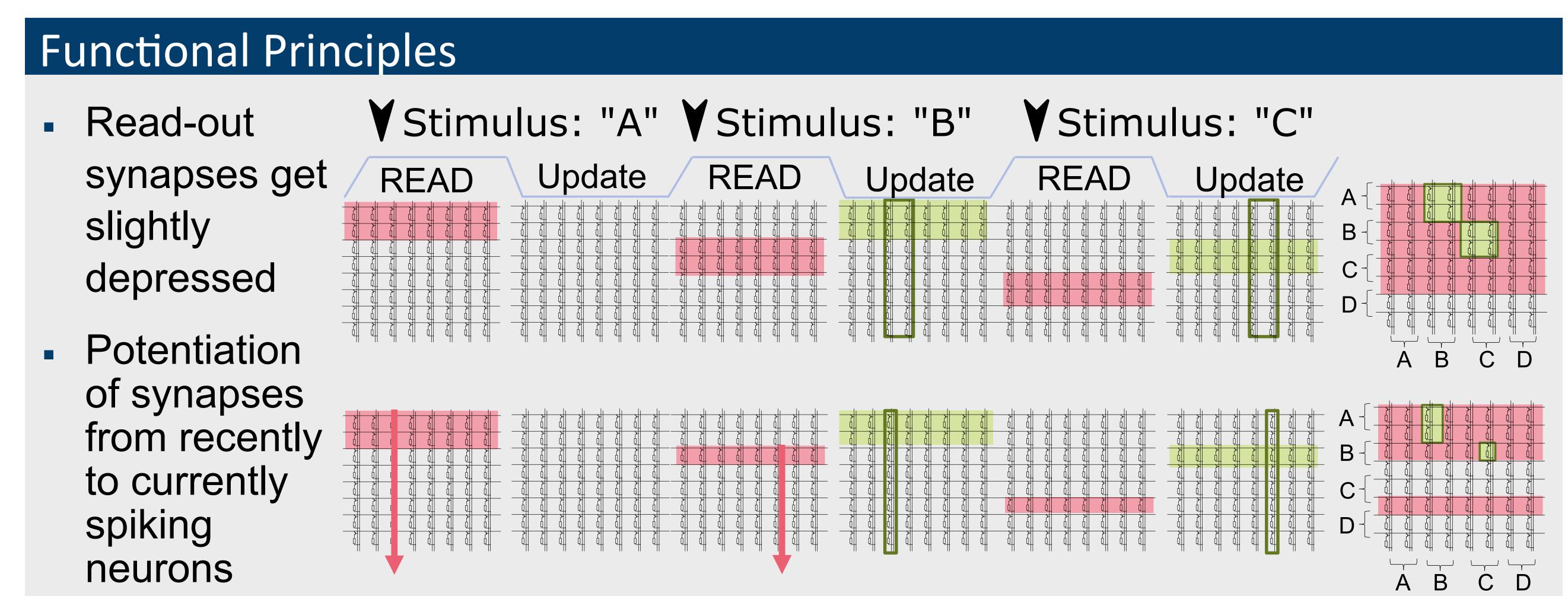
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Sequence learning Sequence learning is considered a core functionality of the human brain Context-sensitive prediction: not only the inputs ADBE FDBC ... ADBE FDBC predictions D B C immediate past symbol prediction error is important. 0% (Hierarchical) Biological Adapt for SpikingTM^[2] MemSpikingTM^[3] Temporal Synapses memristive &Neurons Memory^[1] array

System layout Memristive crossbar array with 130nm CMOS process and HfO ReRAM devices Recurrent connectivity of array via neurons Global (simulated in software) Neurons ordered in sub-B populations (one per character) Hebbian learning rule a) Dendritic Spike in current External time step with homeostatic input current Stimulus **READ Phase** control implemented Open vertical tran-Above sistor gates! completely in Spike in last Update peripheral neuron YES/ No prediction in time step? Phase this epoch yet? circuits YES Potentiation pulse to PREDICTIVE! horizontal inputs! Predictive?

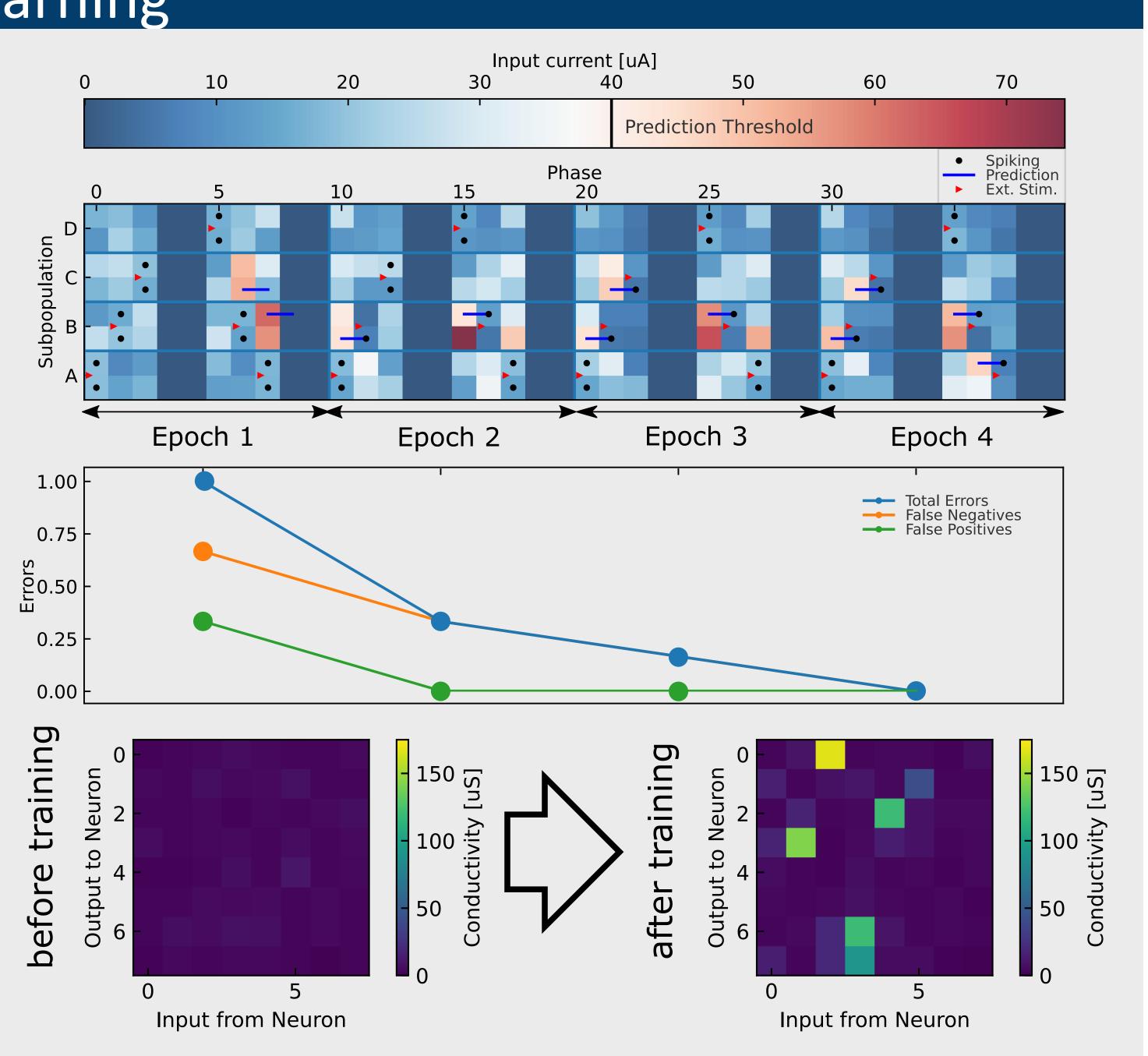
[1] Hawkins, J., & George, D., "Hierarchical temporal memory: Concepts, theory and terminology".

Numenta Inc., (2006).

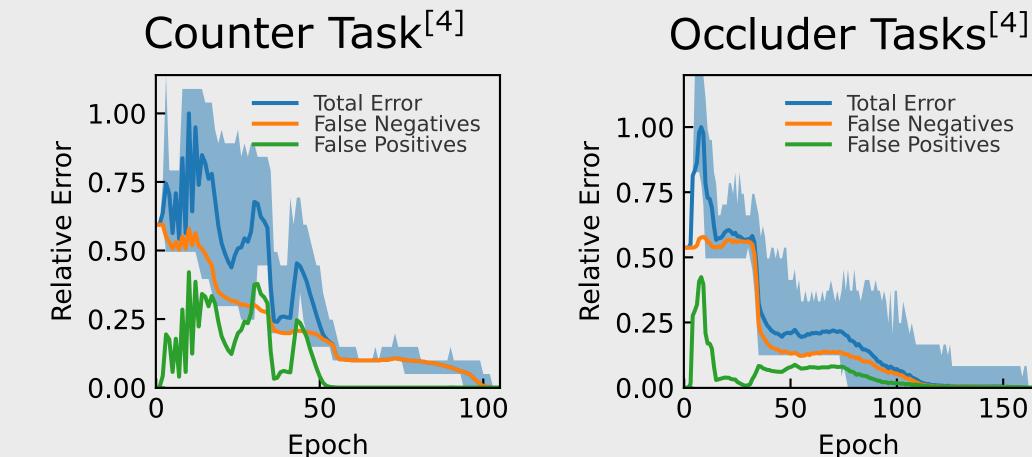


On-chip High-order Sequence Learning

- Predictions are generated gradually and false predictions corrected.
- Context-sensitive predictions achieved by separate prediction in B
- Separate conductive pathways ensured by homeostasis condition
- Sparse high conductive matrix evolving during training







Floating GateMemristive devices 8 1000

- Sequence learning benchmark tasks solved on 60 neuron system in simulation
 - 60% energy savings of memristve over floating gate memory

[3] Siegel et al. "System model of neuromorphic sequence learning on a

memristive crossbar array." Neurom. Comp. and Engin. (accepted)