Diverse synaptic plasticity mechanisms orchestrated to form and retrieve memories in spiking neural networks

Zenke et al. 2015

Ankur Sinha @ UoB

16/11/2016

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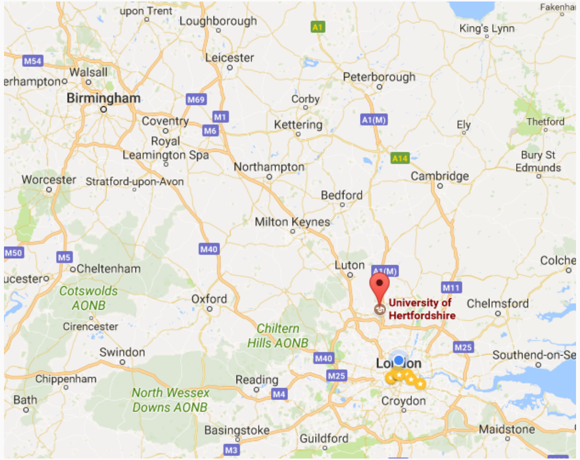

PhD candidate (final year!) @
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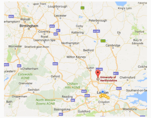

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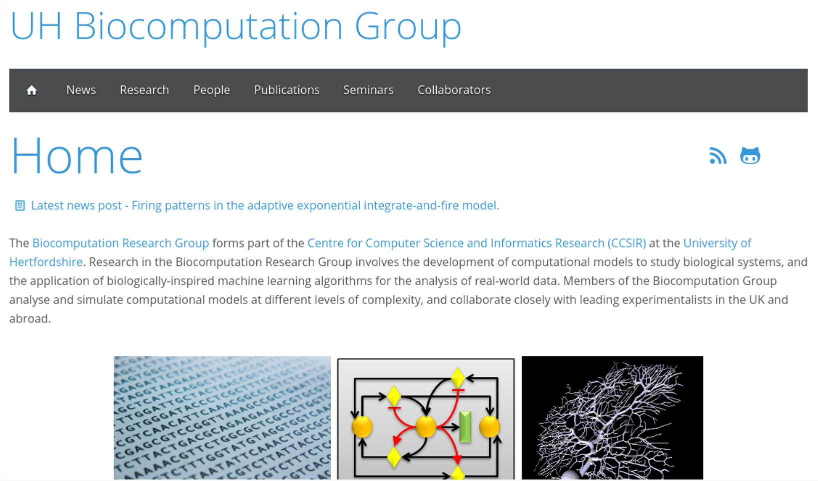

http://biocomputation.herts.ac.uk

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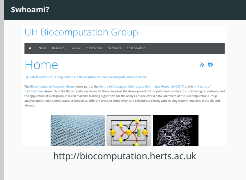

Memory research?

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Functional effects of structural plasticity
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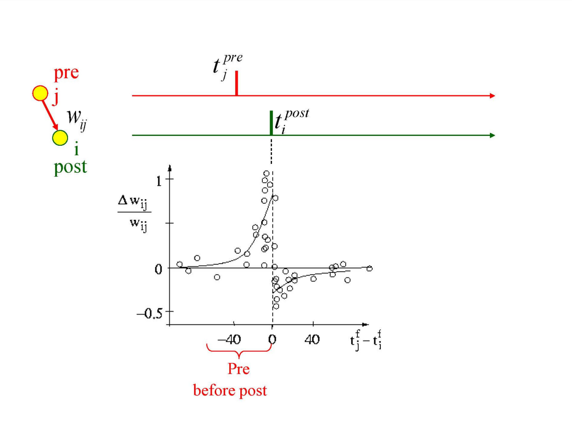
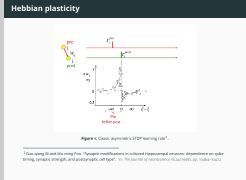


Figure 1: Classic asymmetric STDP learning rule[1].

[1] Guo-qiang Bi and Mu-ming Poo. "Synaptic modifications in cultured hippocampal neurons: dependence on spike timing, synaptic strength, and postsynaptic cell type". In: *The journal of neuroscience* 18.24 (1998), pp. 10464–10472



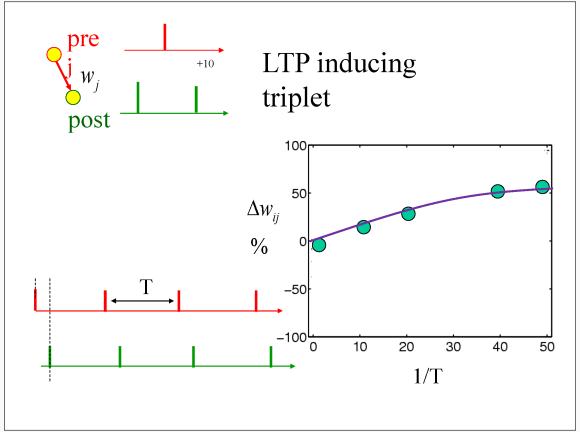
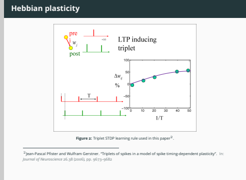


Figure 2: Triplet STDP learning rule used in this paper[2].

[2]Jean-Pascal Pfister and Wulfram Gerstner. "Triplets of spikes in a model of spike timing-dependent plasticity". In: *Journal of Neuroscience* 26.38 (2006), pp. 9673–9682



Effect of Hebbian plasticity

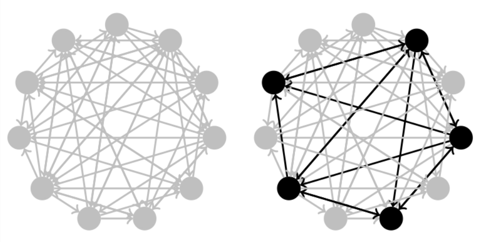


Figure 3: Cell assembly

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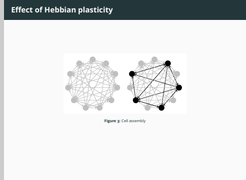

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Effect of Hebbian plasticity: recall

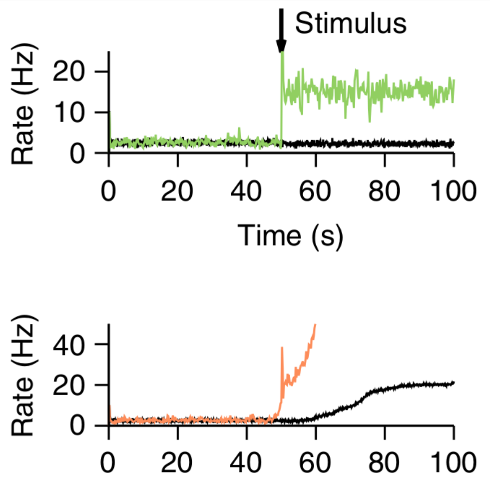

Figure 4: Recall without (top) and with (bottom) Hebbian plasticity.

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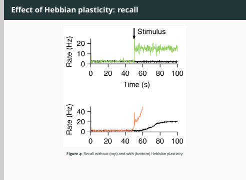

Effect of Hebbian plasticity: dynamics

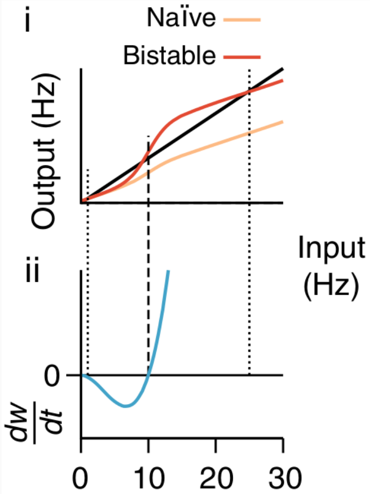

Figure 5: Network (top) and synaptic (bottom) dynamics—uncontrolled increase in synaptic weights at higher firing rates—in the presence of Hebbian plasticity in isolation.

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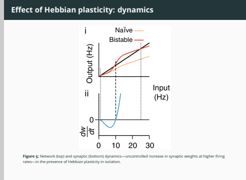

Addition of non-Hebbian plasticity I: heterosynaptic plasticity

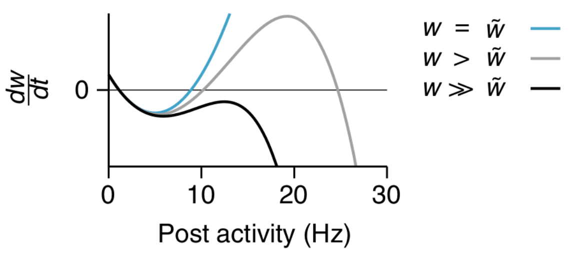

Figure 6: Synaptic dynamics vary depending on their relation to the reference weight—preventing unlimited potentiation

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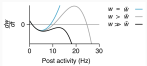

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Addition of non-Hebbian plasticity II: transmitter induced plasticity

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The transmitter induced plasticity increases weights depending on the activity of the pre-synaptic neuron, therefore, preventing uncontrolled depression.

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Resultant dynamics

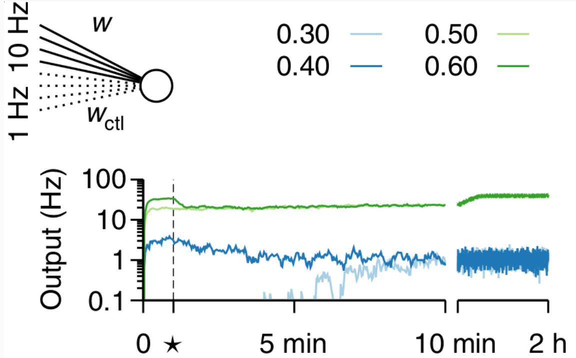
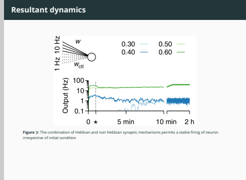


Figure 7: The combination of Hebbian and non Hebbian synaptic mechanisms permits a stable firing of neuron irrespective of initial condition



Global inhibition further stabilises network

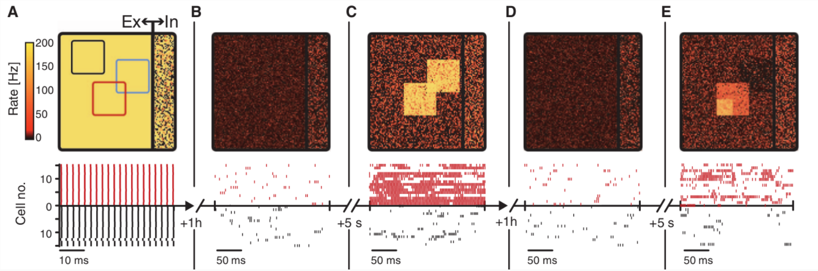
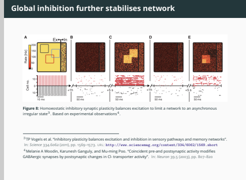


Figure 8: Homoeostatic inhibitory synaptic plasticity balances excitation to limit a network to an asynchronous irregular state[3]. Based on experimental observations[4].

[3]TP Vogels et al. "Inhibitory plasticity balances excitation and inhibition in sensory pathways and memory networks". In: *Science* 334.6062 (2011), pp. 1569–1573. URL: http://www.sciencemag.org/content/334/6062/1569.short

[4]Melanie A Woodin, Karunesh Ganguly, and Mu-ming Poo. "Coincident pre-and postsynaptic activity modifies GABAergic synapses by postsynaptic changes in Cl- transporter activity". In: *Neuron* 39.5 (2003), pp. 807–820



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