On the role of noisy spontaneous activity in heterosynaptic plasticity

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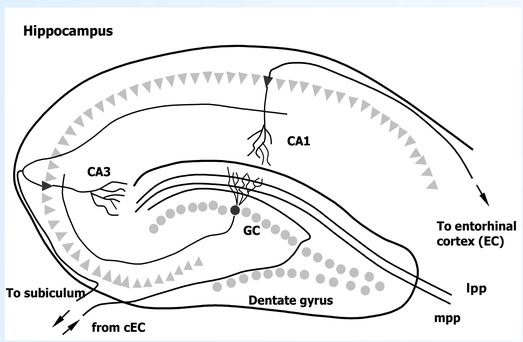
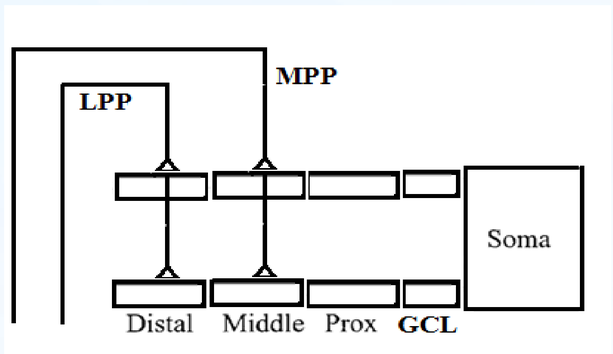
INTRODUCTION

Long-term potentiation (LTP) and long-term depression (LTD) are two forms of synaptic plasticity that underlie learning and memory. To investigate the real experimental studies by Abraham (2007) we have simulated synaptic plasticity of medial and lateral perforant pathways (MPP and LPP) on to a dentate granule cell (GC) with noisy input background activity for three different protocols .

METHODS

To the model dentate GC, we used the reduced morphology compartmental model introduced by Santhakumar [3] implemented in NEURON.





STDP rules

As well as the frequency of presynaptic spiking, precise timing of pre- and postsynaptic spiking activity is also important for LTP and LTD induction. This timing property is called spike-timing dependent plasticity (STDP):

$$\Delta w_+(\Delta t) = A_+ \exp(-\Delta t / \tau_+) \quad \text{if } \Delta t > 0$$
$$\Delta w\_(\Delta t) = A\_ \exp(\Delta t / \tau\_) \quad \text{if } \Delta t < 0$$

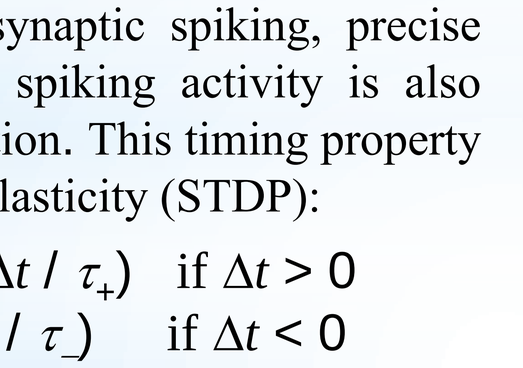
STDP leads to BCM rule for the nearest neighbour STDP, i.e.

$$w(t+1) = w(t)\,(1 + \Delta w_+ - \Delta w\_)$$

With the LTD / LTP threshold $\vartheta = -\dfrac{A_+/\tau\_ + A\_/\tau_+}{A_+ + A\_}$

STDP rule with metaplasticity, i.e. when previous activity affects current plasticity [1]:

$$A_+(t) = A_+(0)\,(1 / \langle V(t)\rangle_\tau)$$
$$A\_(t) = A\_(0)\,\langle V(t)\rangle_\tau$$

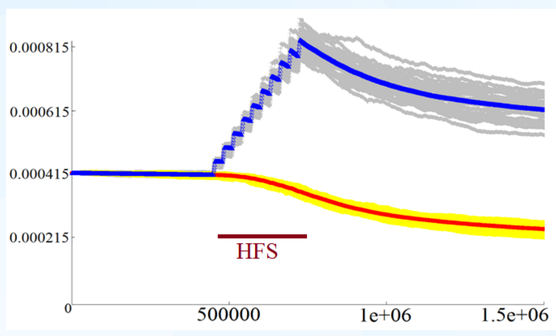


Where <*V*> is the recent average of the somatic PSP; τ = 1 min. Recently, this phenomenon was termed fast (synaptic) homeostasis.

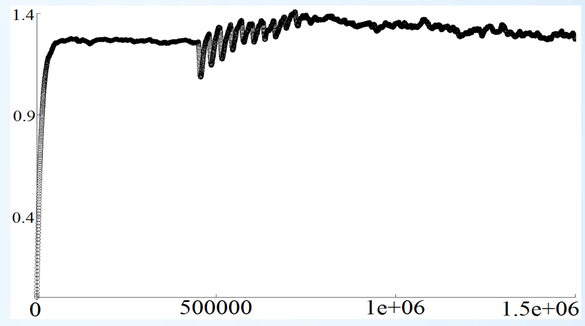
RESULTS AND CONCLUSION

First protocol: Noisy spontaneous activity was applied to both the LPP and MPP pathways during the entire simulation. Mean frequency < 10 Hz; ISI = (1–noise) ISI_0 * negexp(noise*ISI_0). High frequency stimulation (HFS) (50 trains of 10 pulses at 400 Hz) was applied to MPP and this generated homosynaptic LTP of the MPP pathway and heterosynaptic LTD at the LPP pathway [2].

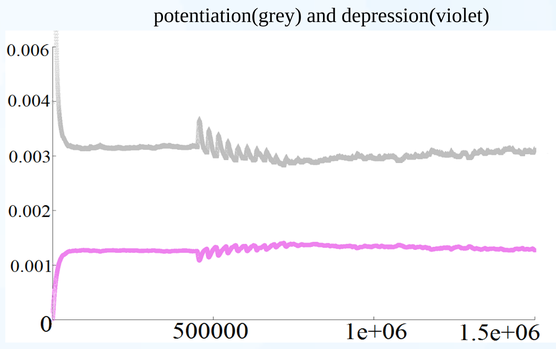
Weights: MeanLPP(red) and MPP(blue)



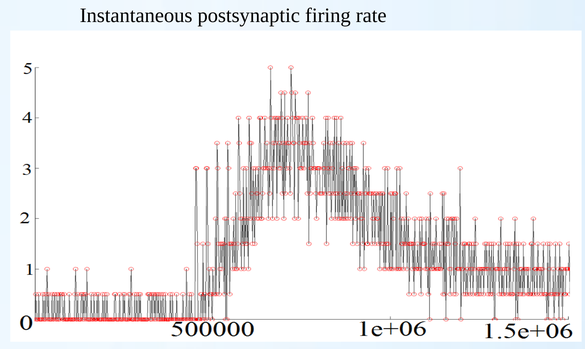
Average postsynaptic somatic *V*



potentiation(grey) and depression(violet)

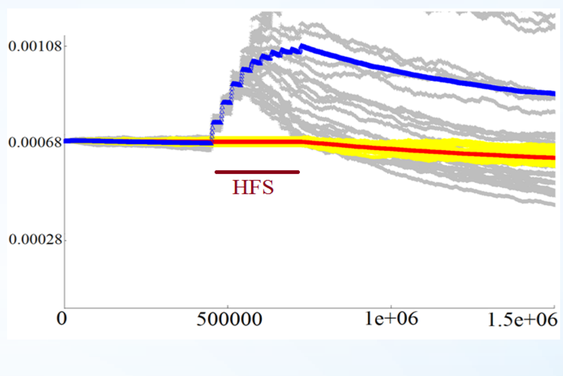


Instantaneous postsynaptic firing rate

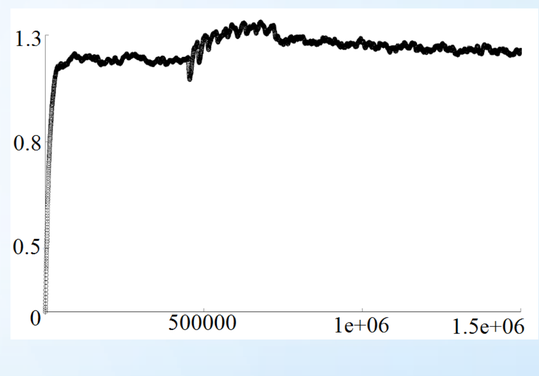


Second protocol: Setting LPP spontaneous activity to zero durring MPP HFS blocked LTD in the LPP pathway.

Weights: MeanLPP(red) and MPP(blue)



Average postsynaptic somatic *V*



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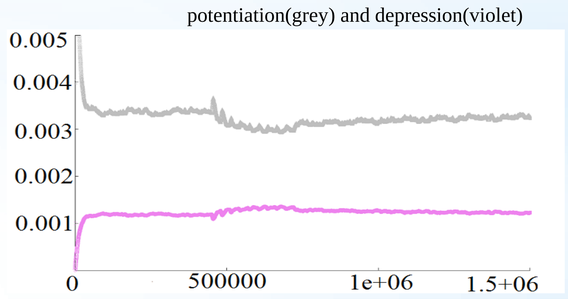
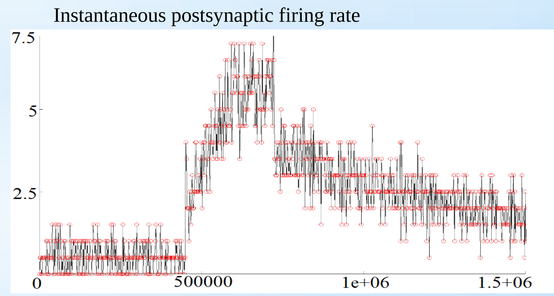
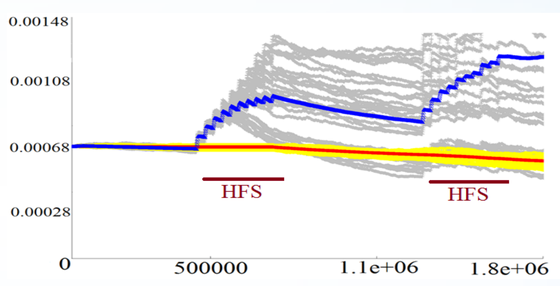


Instantaneous postsynaptic firing rate

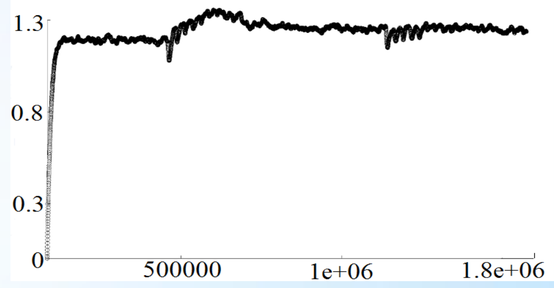


Third protocol: Giving a second HFS to the MPP with normal LPP spontaneous activity still failed to produce LTD

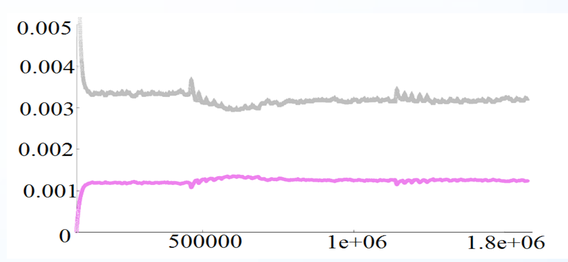
Weights: MeanLPP(red) and MPP(blue)



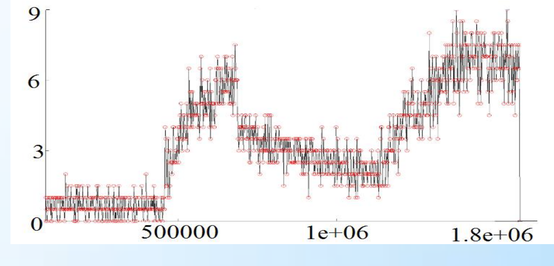
Average postsynaptic somatic *V*



potentiation(grey) and depression(violet)



Instantaneous postsynaptic firing rate



We concluded that noisy ongoing spontaneous activity is critical for inducing heterosynaptic plasticity.

REFERENCES

[1] Benuskova L, Abraham W.C. (2007) , *J. Comp. Neurosci*., vol. 22, pp. 129-133

[2] Abraham WC, Logan B, Wolff A, and Benuskova L (2007), *Journal of Neurophysiology*, vol. 98, pp. 1048-1051.

[3] Santhakumar V, Aradi I, and Soltesz I (2004), *Journal of Neurophysiology,vol.* 93,pp. 437–453.