Characterizing the role of activity-dependent homeostatic plasticity in central pattern generators

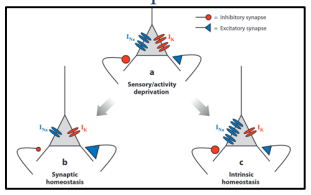
Lindsay Stolting, Eduardo Izquierdo, Randall D. Beer

Program in Neuroscience, Cognitive Science Program, Indiana University Bloomington

BACKGROUND

Activity-dependent Homeostatic Plasticity (HP)

- Neurons regulate their excitability to remain within ideal activation range
- Tune the strengths of their incoming synapses and ionic conductances
- Grants robustness to perturbation



Adapted from (Turrigiano, 2011), Fig.1

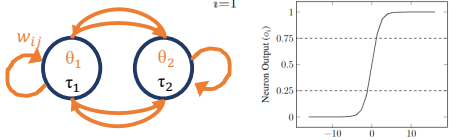
QUESTIONS

1. Does HP increase the chance a circuit will oscillate (be a central-pattern generator)?
2. If so, *how* is this accomplished?

MODEL & MEHODS

Continuous-time recurrent neural network (CTRNN)

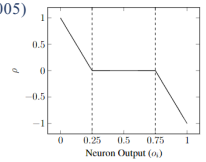
$$\tau_i \frac{dy_i}{dt} = -y_i + \sum_{i=1}^{N} w_{ji}\sigma(y_j + \theta_j) + I$$



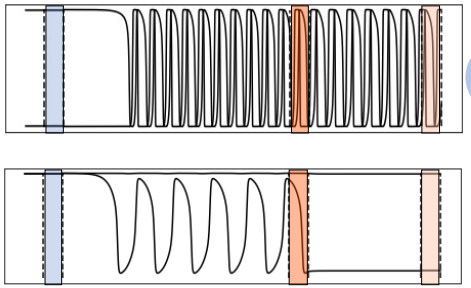
HP mechanism (Williams, 2005)

$$\tau_w \frac{dw_{ji}}{dt} = \rho_i|w_{ji}|$$

$$\tau_\theta \frac{d\theta_i}{dt} = \rho_i$$

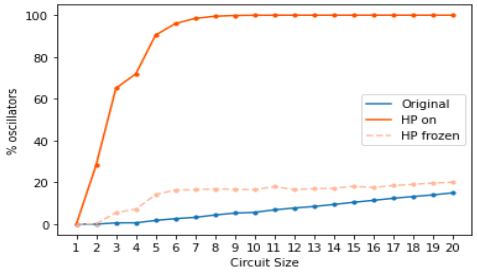


DOES HP INCREASE % OF OSCILLATING CIRCUITS?



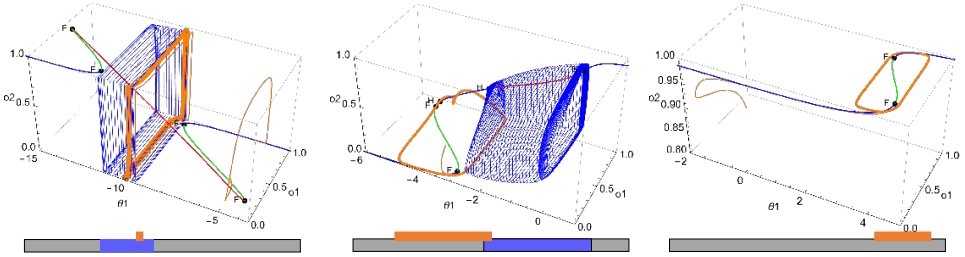
- Circuits oscillate more often when HP active
- Effect ↑ with circuit size

- Freezing HP also froze oscillations in most (though not all) cases → oscillations depend on HP
- Most circuits do not simply get "pushed" into an osc. region of parameter space and remain there



HOW DOES HP GENERATE OSCILLATION?

Simplified system: 2-neuron circuit with one parameter under homeostatic control (θ_1)



- HP-driven limit cycle never leaves the oscillatory range of θ_1
- θ_1 stays in narrow range
- Freezing HP does not freeze oscillation

- HP-driven limit cycle goes in and out of the oscillatory range
- θ_1 noticeably fluctuates
- Freezing HP sometimes freezes oscillation

- The base (non-HP) system has no oscillatory activity
- θ_1 noticeably fluctuates
- Freezing HP always freezes oscillation

DISCUSSION/CONCLUSION

- HP can cause neural parameters themselves to oscillate, resulting in state oscillations
- Changing neural parameters should be considered *states* of the system rather than parameters
- Even though the timescale of HP is slower than neural activation, it may still be behaviorally relevant
- HP may play important roles during normal function, not just in response to perturbation
- HP is capable, not only of maintaining CPGs, but actually *driving* them

FUTURE DIRECTIONS

- How does HP mechanism implementation affect HP-driven oscillations (i.e., timescale, target range)?
- How does the robustness of HP-driven oscillations compare to HP-maintained oscillations and non-HP systems?
- What patterns of neural parameter change can be observed empiracally?
- What is the real timescale of HP relative to neurons?

REFERENCES

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CONTACT

Lindsay Stolting, lstoltin@iu.edu