Sequence learning with the BCPNN rule

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Sequence Learning

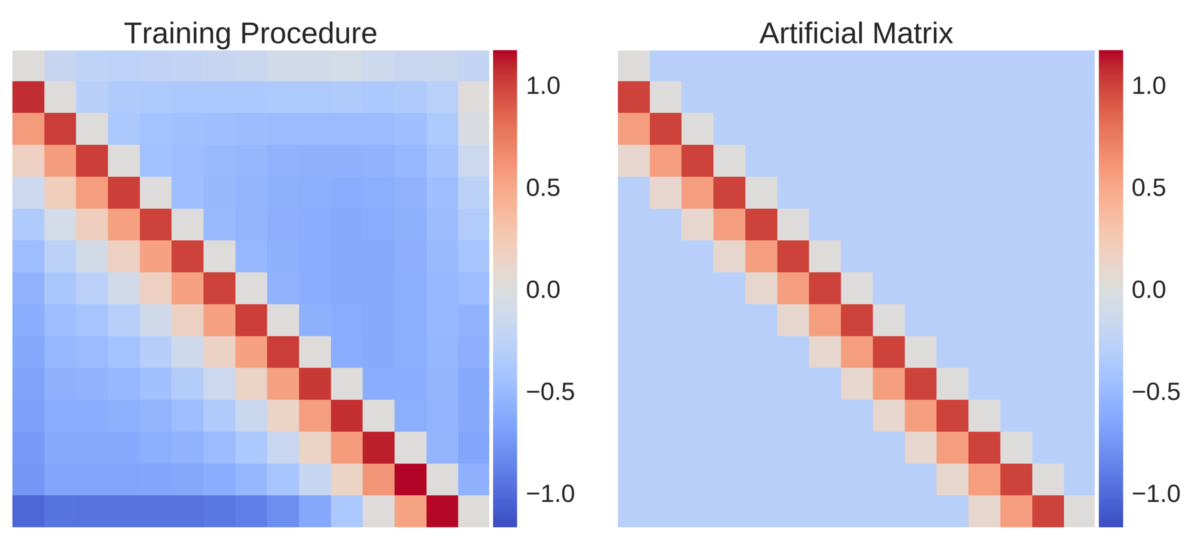
How can neocortical microcircuits encode sequences of activity? How can a stable sequential dynamics self-organize withing the bounds of the biological constrains? As early as 1950 Karl Lashley [3] advocated that the ability to sequence actions is the essential cognitive ability of human, how can we account for it? Since then we have found sequential population bursts in the activity related to the following behaviors:

- Motor
- Sensory
- Memory
- Decision Making

Here we propose a generic model that is a step ahead in solving the riddles above.

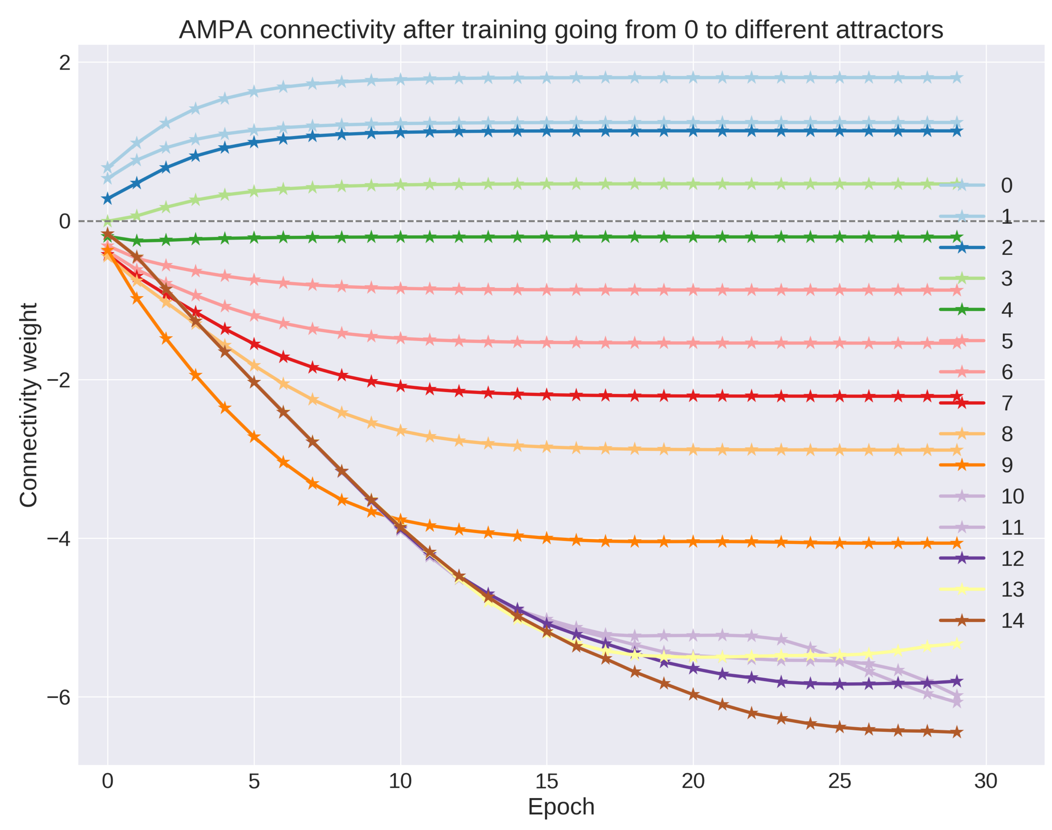
Artificial Connectivity Matrix

In order to simplify the parameter search we use an artificial connectivity matrix that we build to simulate the connectivity matrix that results from a natural training process.



Stability across training

This and that



References

[1] Tully, Philip J., Henrik Lindén, Matthias H. Hennig, and Anders Lansner. e1004954. *PLoS Comput Biol 12, no. 5 (2016)*

[2] Sandberg, Anders, Anders Lansner, Karl Magnus Petersson, and Ekeberg 371(1):179-194 *Network: Computation in neural systems 13, no. 2 (2002))*

[3] Lashley, Karl Spencer pp. 112-136 *Cerebral mechanisms in behavior. 1951*

The Model

- Previous work has shown that the BCPNN rule can learn sequences in a spike based attractor model with modular structure [1].
- Using the firing-rate version of the model [2] with both fast (AMPA) and slow (NMDA) connectivity we study the capabilities of the system for pattern and sequence storage. [2].

$$\tau_m \frac{s_i}{dt} = \beta_i + \sum_j w_{ij} o_j + a_i - s_i$$

$$o = \frac{exp(s_i)}{\sum_j exp(s_j)}$$

$$\tau_z \frac{dz_i}{dt} = o_{i,k} - z_i$$

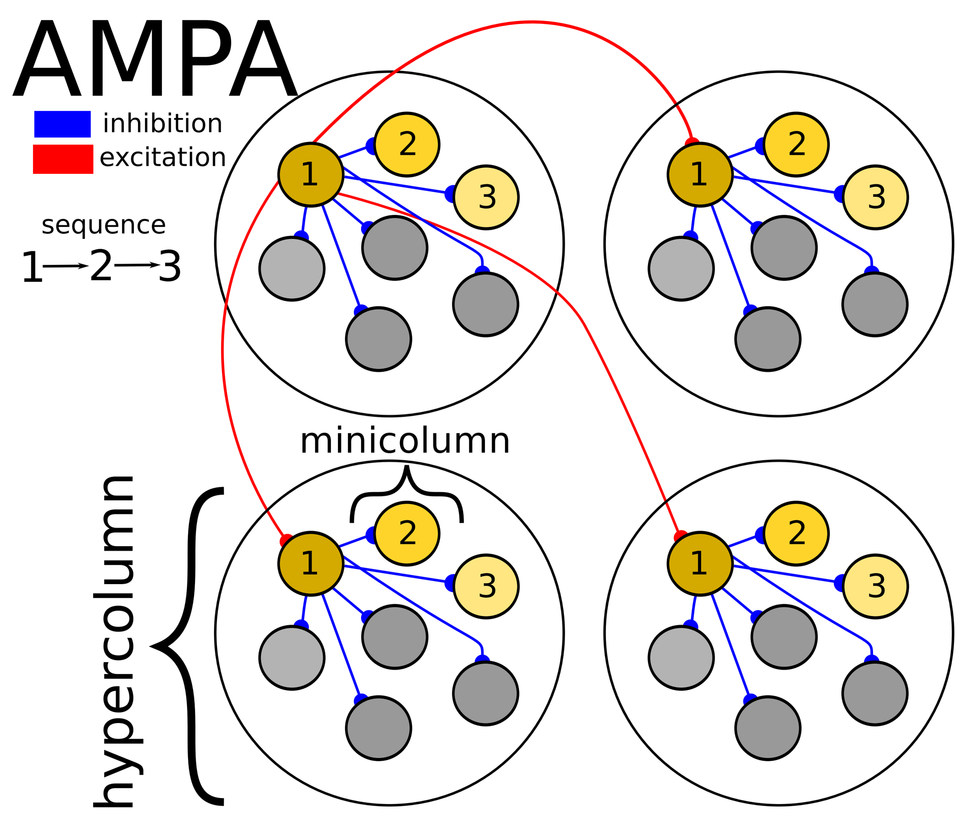
$$\tau_p \frac{dp_i}{dt} = z_i(t) - p_i(t)$$

$$\tau_p \frac{dp_{ij}}{dt} = z_i(t) z_j(t) - p_{ij}(t)$$

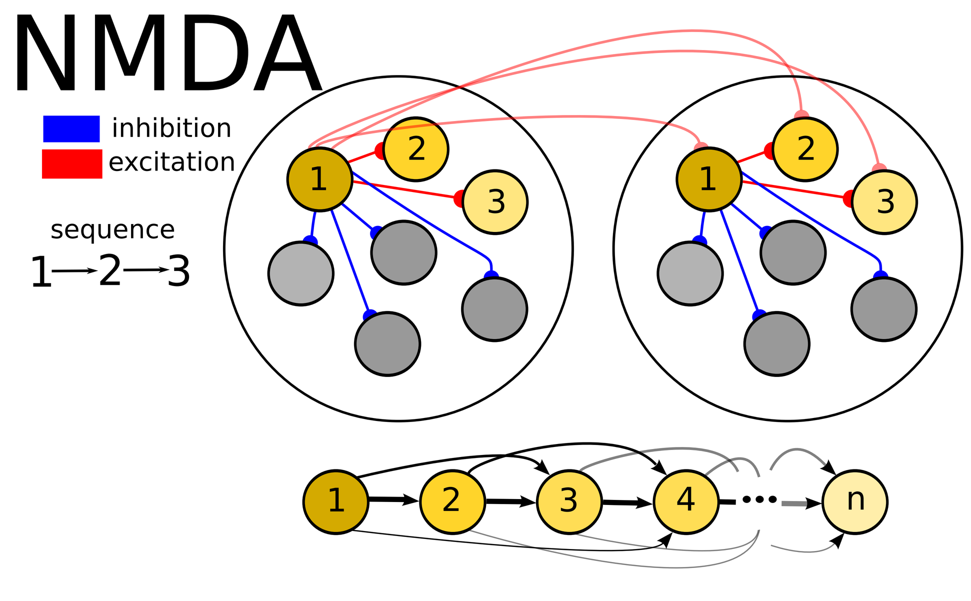
$$w_{ij} = \log(\frac{p_{ij}}{p_i p_j})$$

$$\beta_i = \log(p_i)$$

Due to a local transition rule in absence of noise this model can recall a sequence of arbitrary length. Moreover, it can perform within certain limitations both **sequence completion** and **sequence disambiguation**.

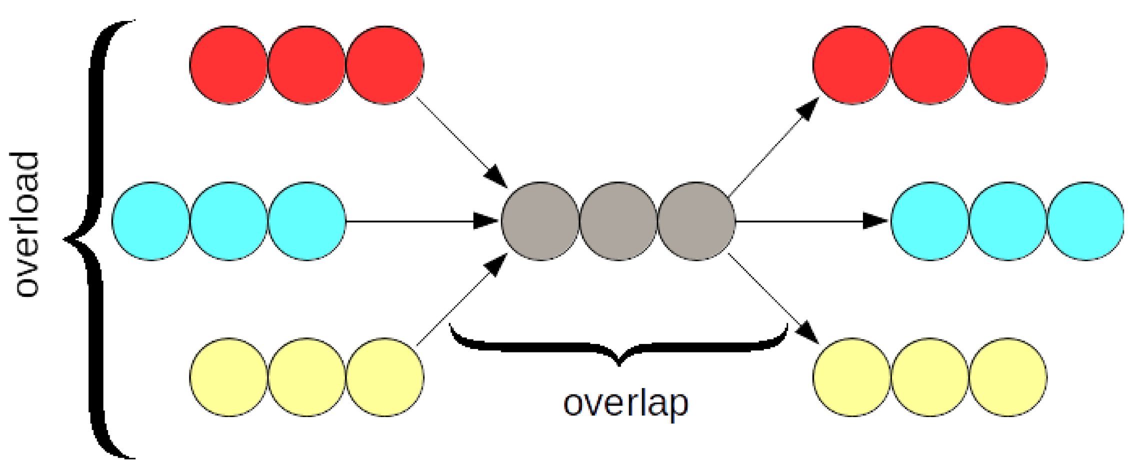


Note that in both diagrams we only show the connections emanating from the first minicolumn in the top-left hypercolumn.



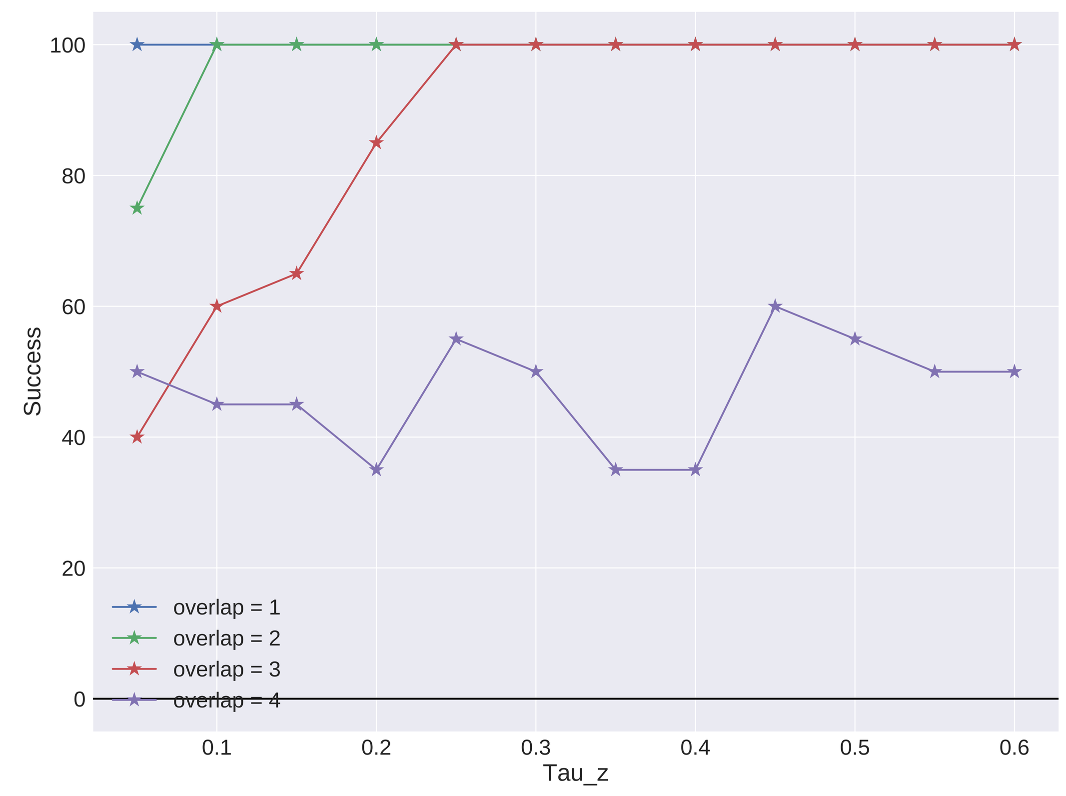
Chains

- We stored more complicated sequences in order to probe how effective is our system at retrieving them.
- Two relevant parameters to parametrize the space of all the possible sequences are **overlap** and **overload**.



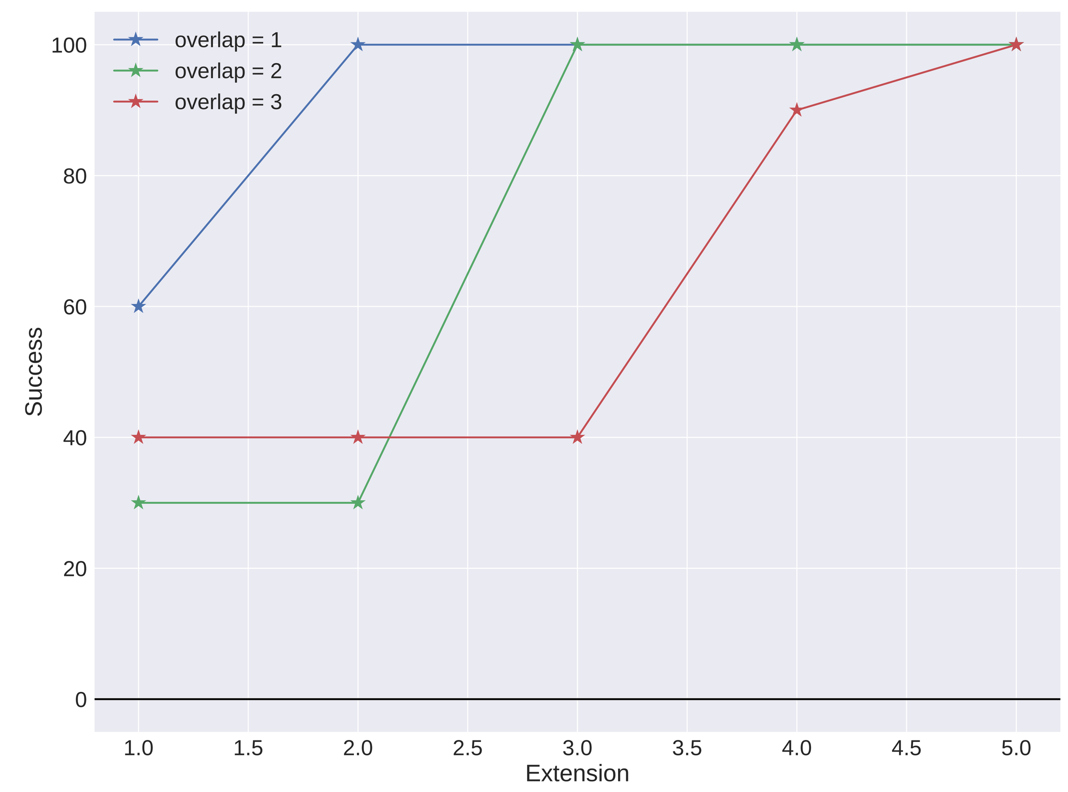
τ_z

This and that



Extension

This and that



Funding

This work was supported by EuroSpin, KTH, ask Pawel for more

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