Oscillatory Neural Model of Spiking Elements for Memorising of Time-Sequencies

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Introduction

There are two main ideas for designing a memory of sequences:

- Chain: To chain consecutive events
- Label: To mark events by ordered labels

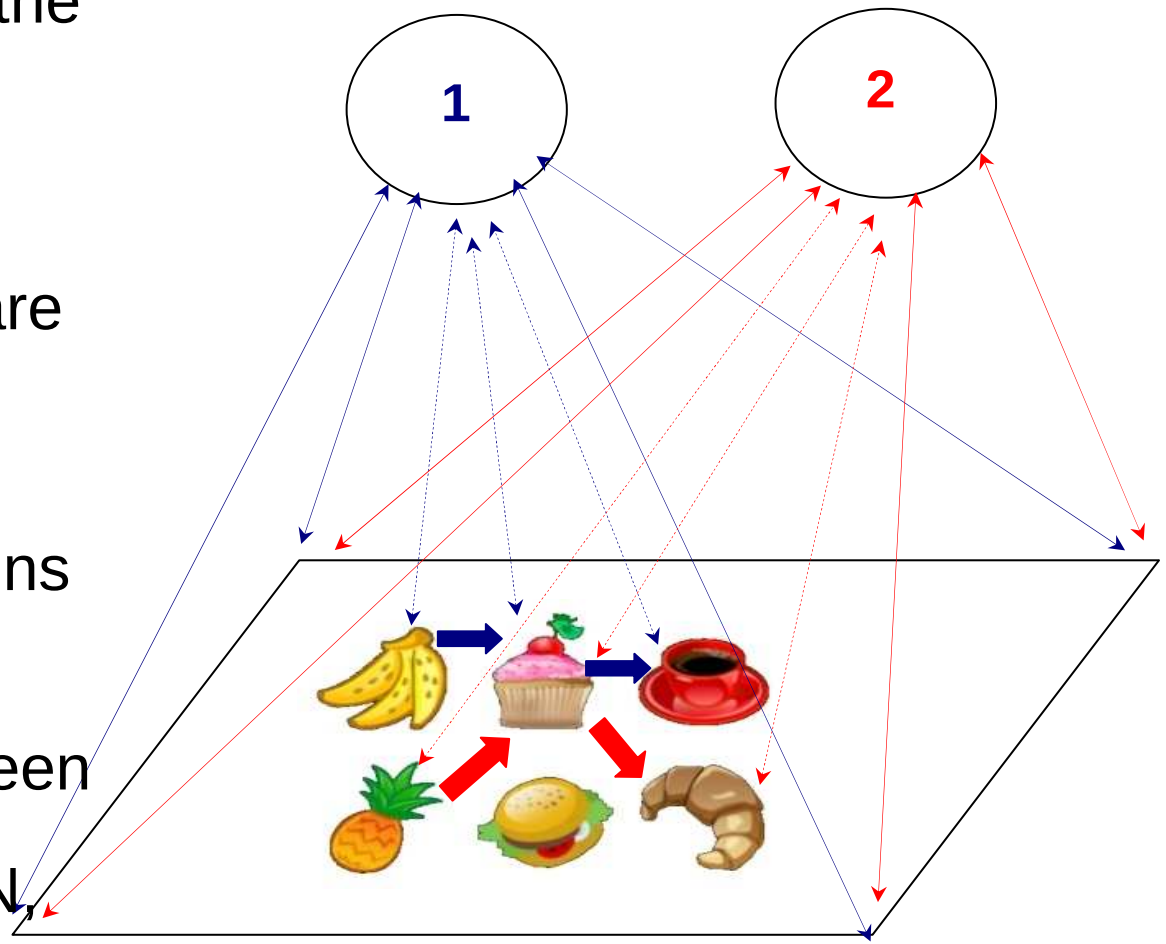
Borisyuk R & Hoppensteadt F (2004) A theory of epineuronal memory. Neural Networks

Oscillatory Model of Spiking Elements

- We develop an oscillatory neural network (ONN) model which is designed as a network of **coupled oscillators**.
- Oscillator comprises **excitatory and inhibitory spiking elements of Hodgkin-Huxley** type with all-to-all connections.
- Connections between oscillators are all-to-all type and they are established between excitatory neurons of different oscillators.
- **STDP type learning rule** takes into account activity level of oscillators in two sequential time windows.

Star-Like Connections

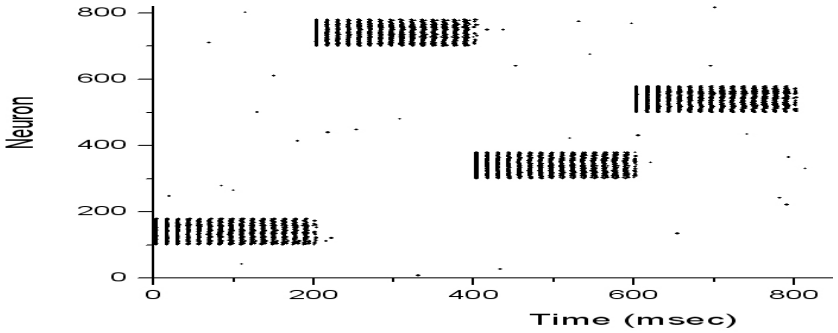
- During memorization the connections between **Central Neuron** (CN) and neurons representing the sequence of objects are adjusted.
- During recall the CN inhibits activities of all neurons except neurons representing the sequence of objects.
- Due to interplay between local connections and global inhibition by CN, **sequences with a common object** (A>B>C, D>B>E) can be recalled.



Memorising a sequence of 6 objects

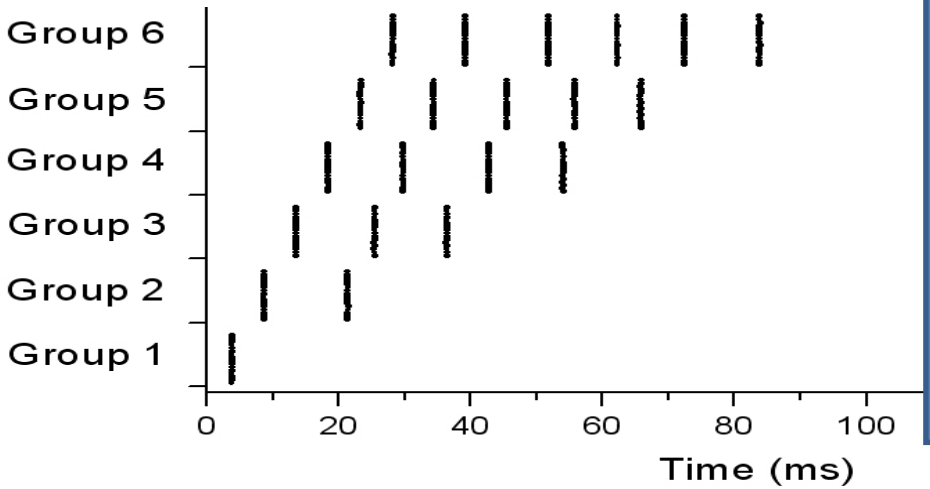
Each object is coded by a set of 20 neural oscillators corresponding to different object' features.

An object presentation means stimulation of corresponding oscillators for 200ms. Objects appear sequentially.

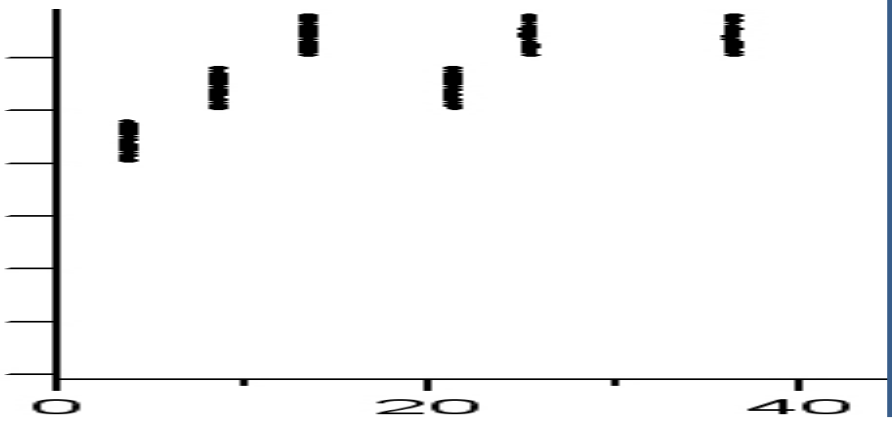


Replay 1 (arrow shows 1st object)

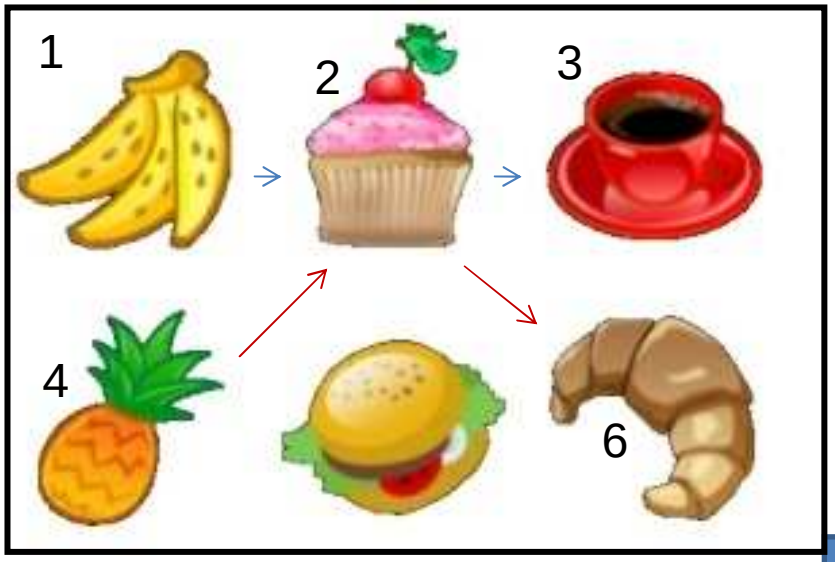
A total duration of replay is 200ms.
Objects appear sequentially with a short delay.



Replay 2 (arrow shows 1st object)



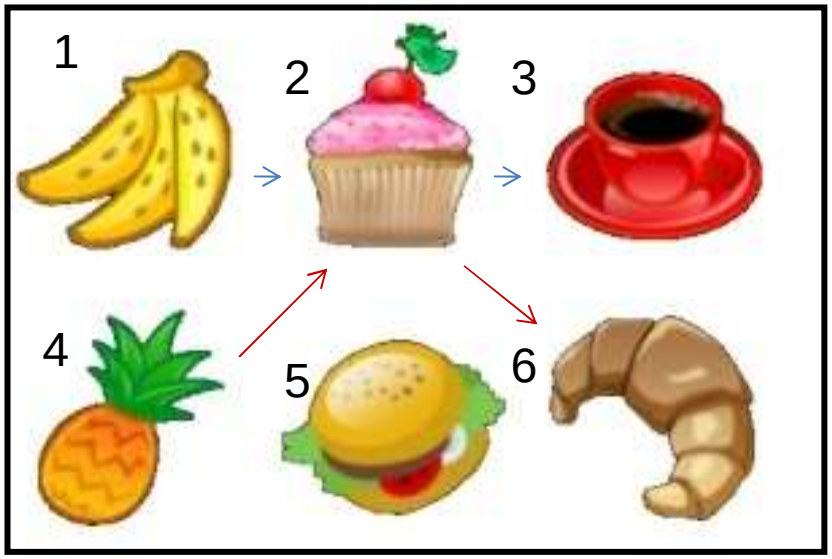
Memorising of two sequences



Blue sequence

Two sequences with a common element:
Blue: 1>2>3
Red: 4>2>6

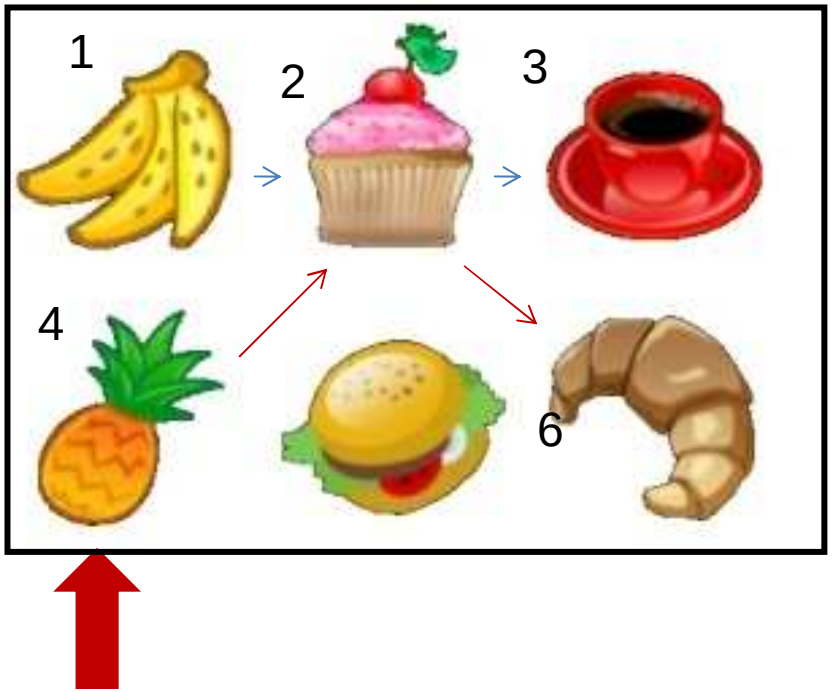
Memorising of two sequences



Red sequence

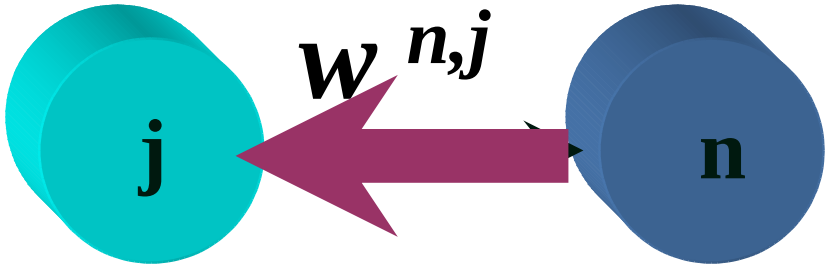
Replay of blue sequence

Replay of red sequence



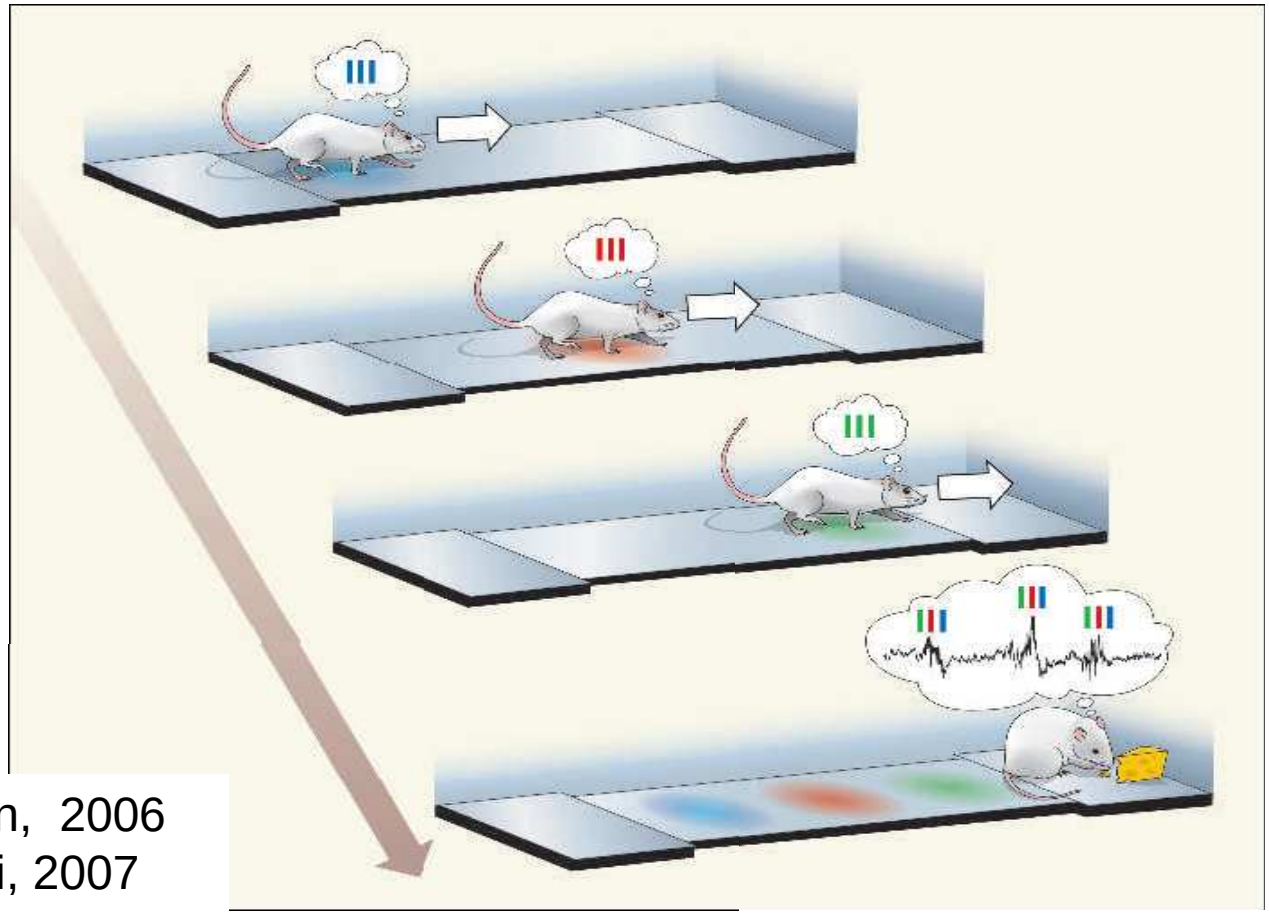
Anti STDP and Reverse Replay

$$w^{n,j}(m+2) = w^{n,j}(m+1) +$$
$$(\alpha+\beta)\cdot\sigma(E^{j}_{\max}(m)-h)\cdot\sigma(E^{n}_{\max}(m+1)-h)-\beta$$



Application: Preplay and Reverse Replay of Hippocampal Place Cells

Borisyuk R, Chik D. 2009. In preparation



Foster & Wilson, 2006
Diba & Buzsaki, 2007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