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Recurrent Neural Networks for Interval Duration Discrimination Task

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Introduction and methods

- We analyse how a randomly connected network of firing rate neurons can perform computations on the temporal features of input stimuli.
- We extend previous work[1,2] and conduct experiments whereby networks of a few hundred neurons were trained to discriminate whether the time between two input stimuli was larger or smaller than a set duration [150 ms].
- The discrimination was achieved by training the readout weights of the network with FORCE learning[3] and an analysis was performed on the state of the network using principal component analysis and temporal mutual information[4].

Simulations

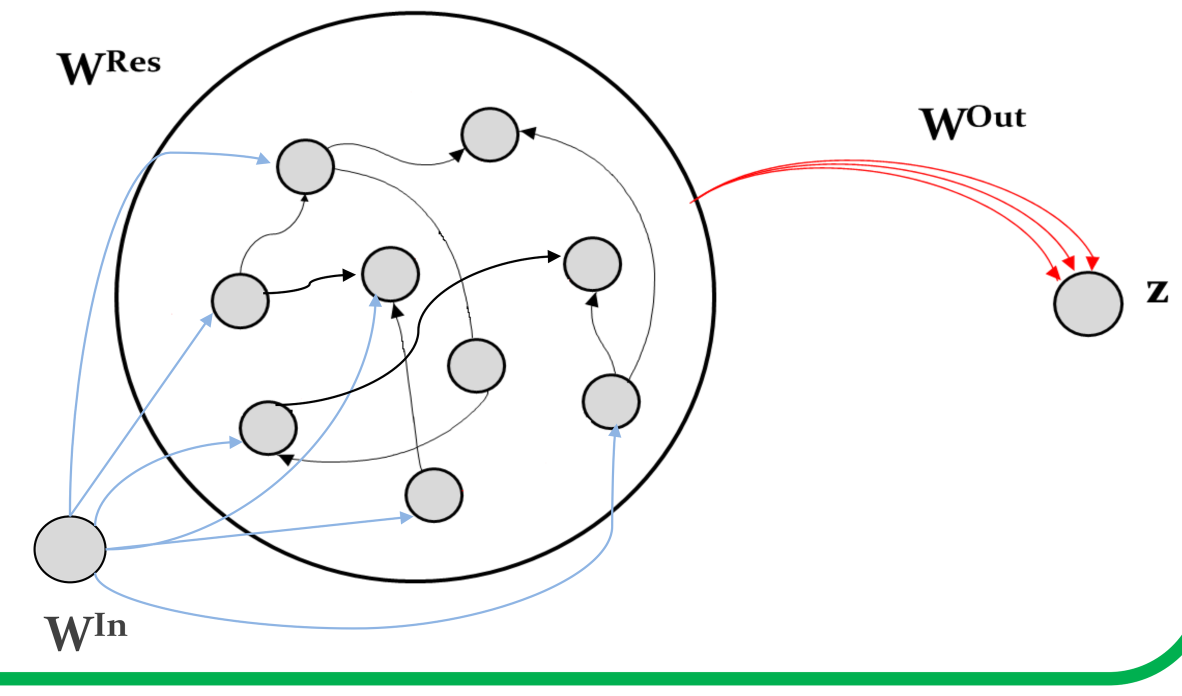
Neuron model

$$\tau \frac{\mathrm{d}x_i}{\mathrm{d}t} = -x_i + \sum_i W_{ij}^{Res} \tanh(x_j) + W_i^{In} Input$$

In the equation, x_i indicates neuron's i membrane potential and τ the time constant of the network.

Network configuration

W^{Res} (black), W^{Out} (red and trainable) and W^{In} (blue) are the connectivity matrices shown the figure.

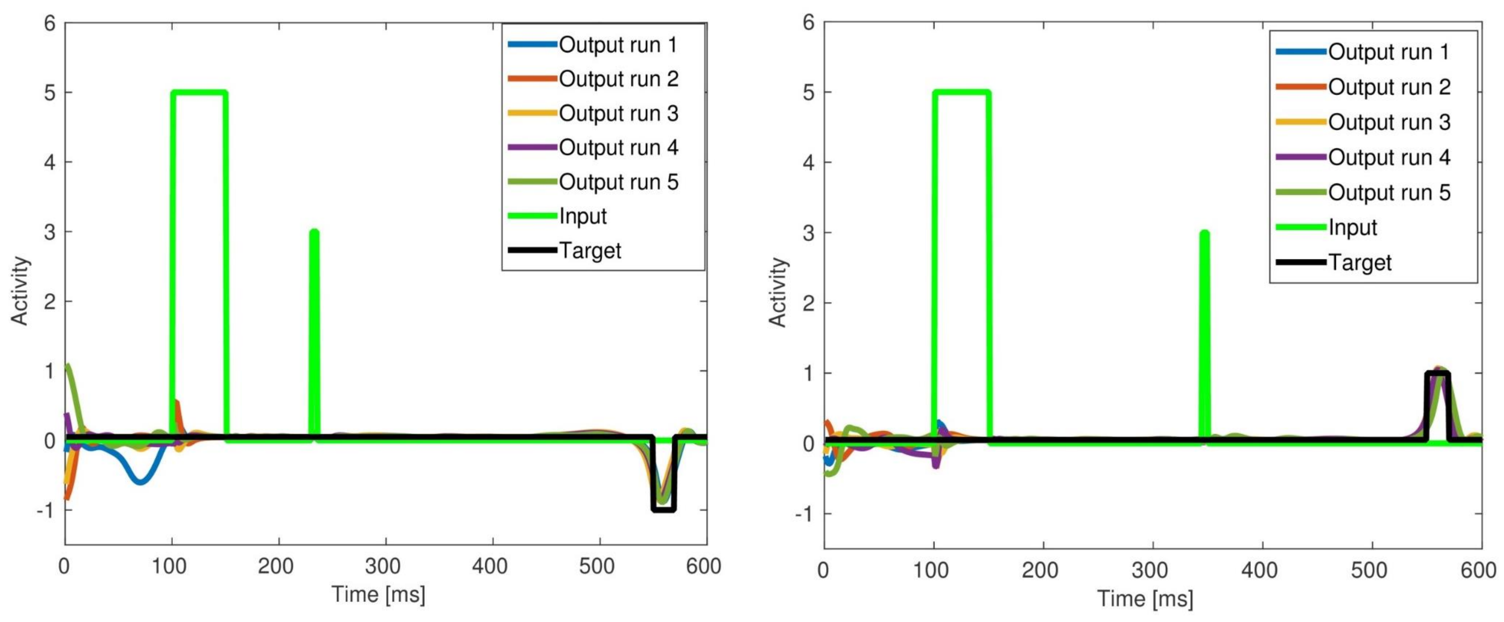


Results

I. Interval duration discrimination experiments

Output

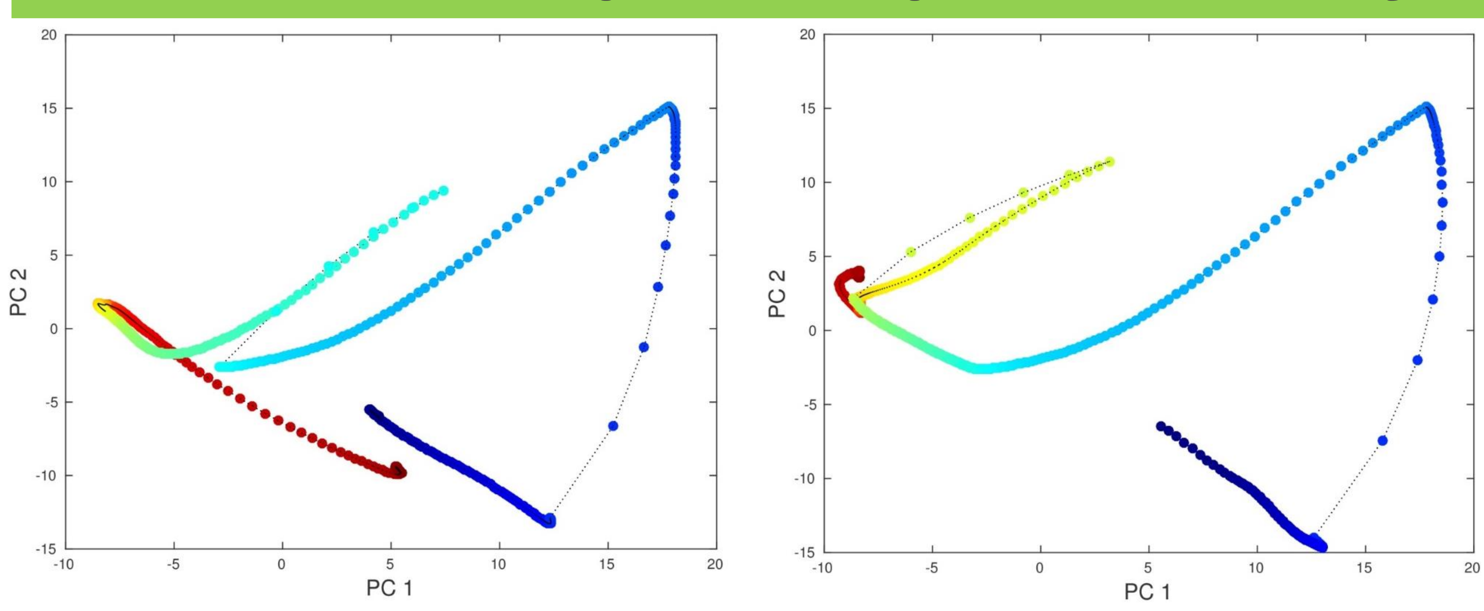
Plots of the network's output activity overlaid on the input (green) and correct output (black).



95.75% Interval Classification Accuracy

- FORCE learning on output weights only can successfully learn to discriminate intervals.
- The temporal computation is encoded in the state of the network.

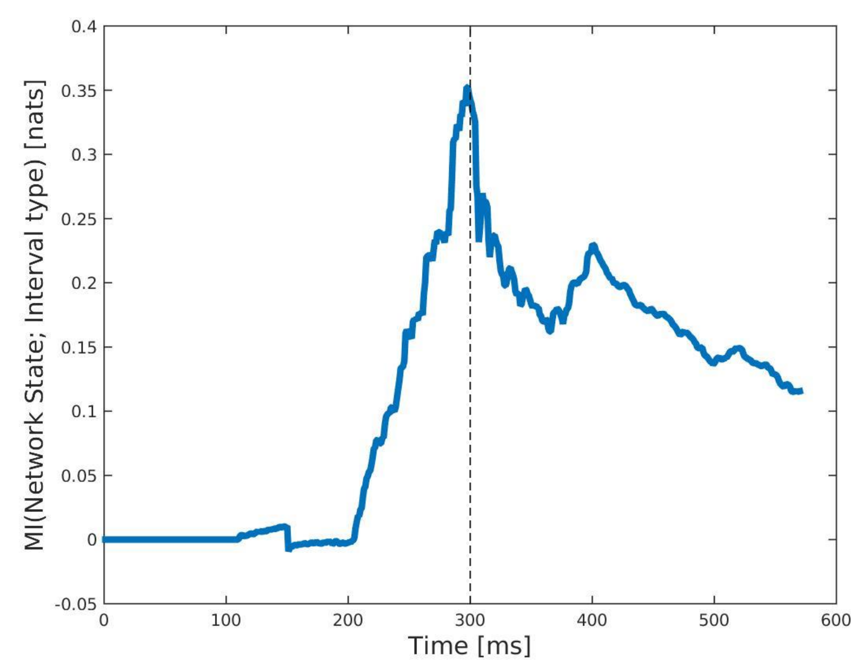
Principal component analysis



Projection of the network activity on its first two principal components.

II. Temporal mutual information (MI)

- Average mutual information between individual neuron state and interval type (short or long) at every timestep.
- Peak at 300 ms indicates the timestep where highest amount of information about interval type can be extracted from a single neuron in the network.



Conclusions

- The dynamical state of the network has an intrinsic temporal memory that can be associated through simple linear readout units with temporal computations such as the interval duration discrimination task.
- Small cortical circuits can perform such temporal computations in a distributed manner.

References

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