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Daniela Pamplona, Bruno Cessac, Pierre Kornprobst

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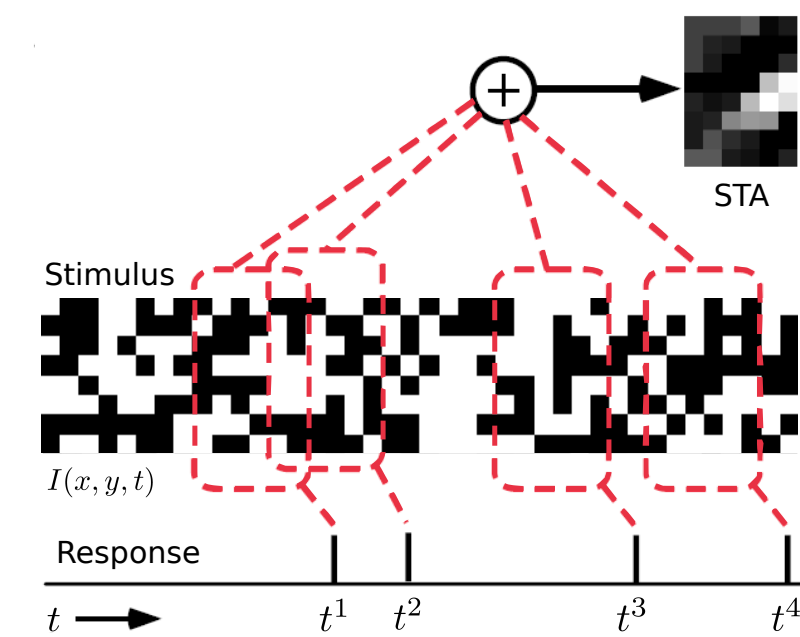
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# Shifting stimulus for faster receptive fields estimation of ensembles of neurons

Daniela Pamplona Bruno Cessac Pierre Kornprobst

## SPIKE TRIGGERED AVERAGE (STA)

The STA is a widely used receptive field (RF) estimator. If the stimulus is white noise, the estimation error tends to zero as the spike count tends to infinity. The speed of convergence depends on the variance of the stimulus and the number of spikes.



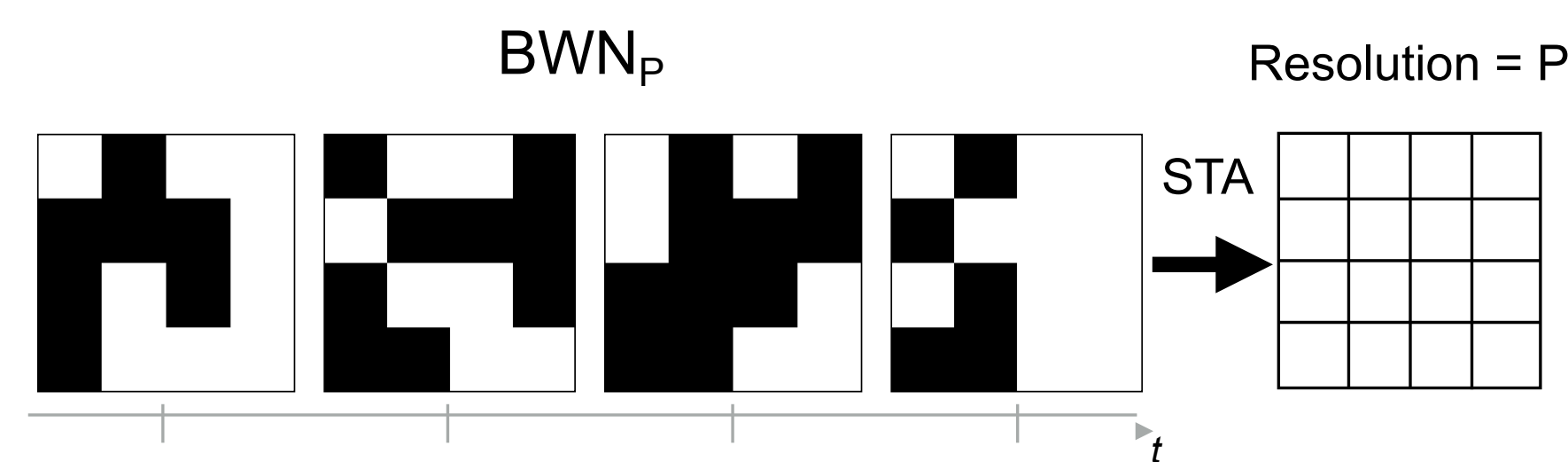
$$\text{Error}(STA, RF) = \sum_{x=0}^X \sum_{y=0}^Y \sum_{z=0}^Z (STA(x, y, z) - RF(x, y, z))^2$$

$$\text{Error}(STA, RF) \sim Z^2 \frac{\sigma^2}{n(T)}$$

Conclusion: For a good estimation, the STA resolution should be fine. To increase the speed of convergence the stimulus variance should be low or the spike count should be high.

## STANDARD STIMULUS

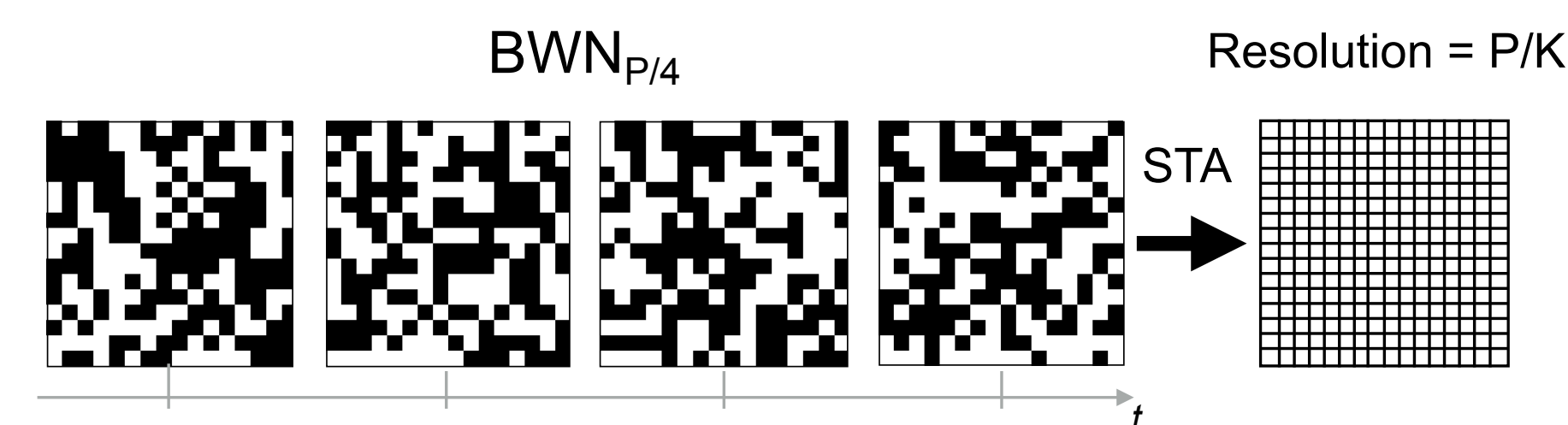
Black and white checkerboards images of block size P:



But... If the block size is too large, the resolution is coarse. The STA might miss RFs or estimate them roughly. Thus, the estimation error might be very high.

## INCREASING THE RESOLUTION

Naive solution: decrease the block size (here K = 4 times)

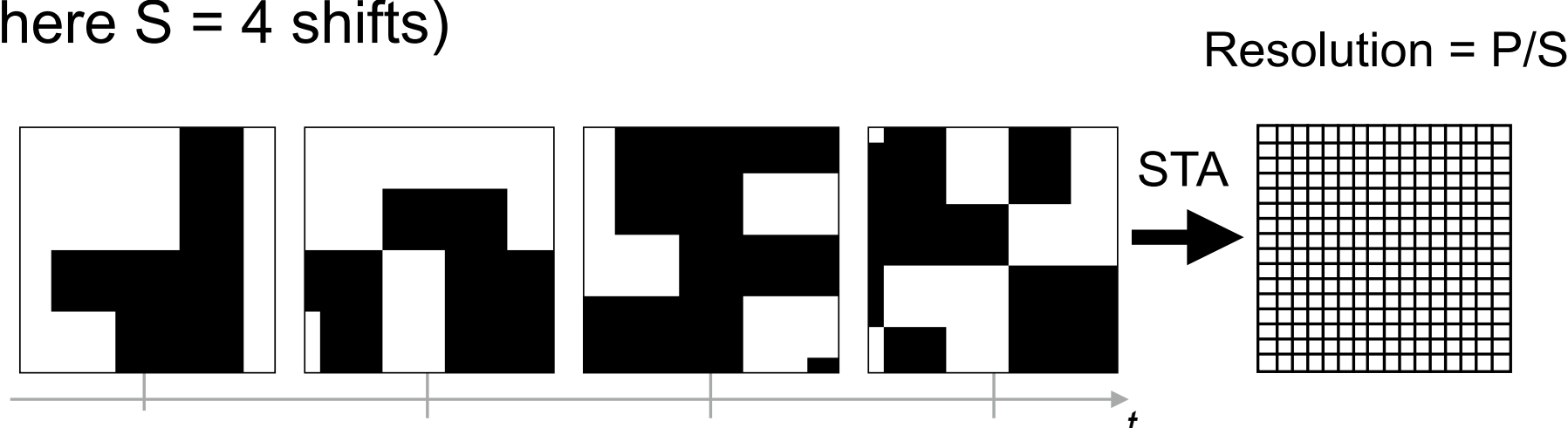


But... If the block size is too small, the spike count might be too low. Therefore the speed of convergence might very slow which can be impractical in an experimental setup.

Problem: How can we define a good stimulus resolution for a neural ensemble?

## PROPOSED SOLUTION

Checkerboard stimulus where blocks are randomly shifted in discrete steps at each time stamp (here S = 4 shifts)



Conclusion: The SWN<sub>P/S</sub> increases the STA resolution without decreasing the block size, thus it is suitable for a large ensemble of neurons.

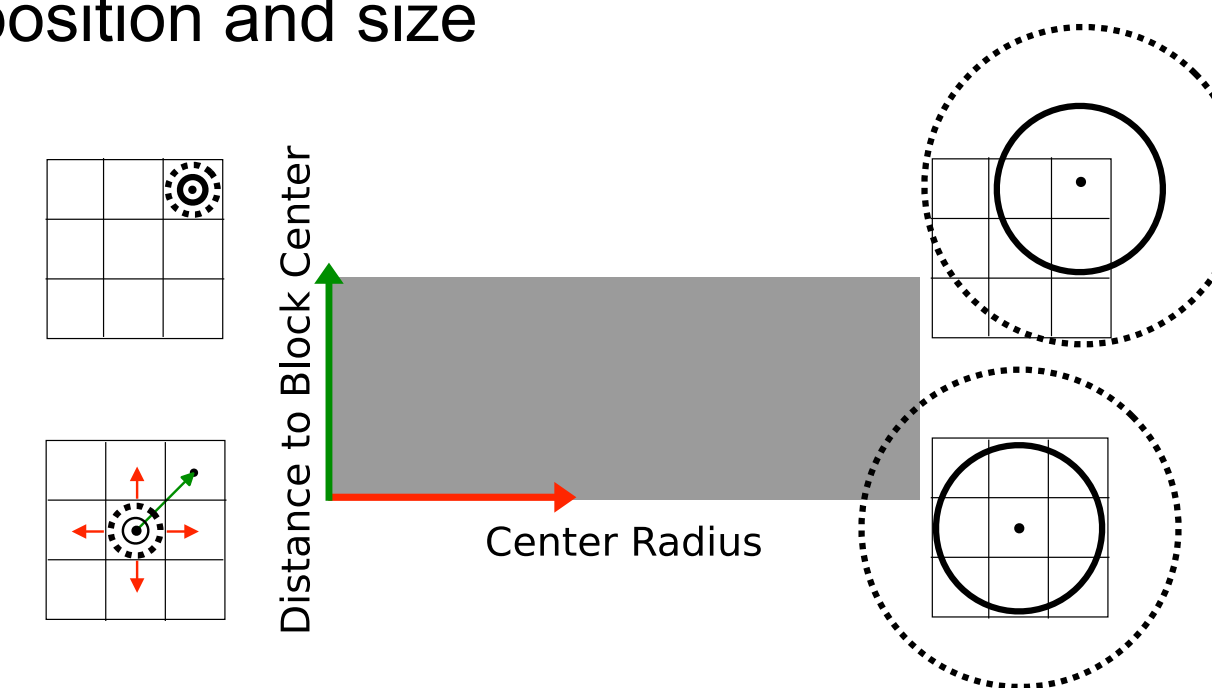
## SIMULATION PROTOCOL

Experimental setup:

- 5 trials, 20000 images per trial, display rate 30Hz
- 3 sets of stimuli: BWN<sub>8</sub>, BWN<sub>2</sub>, SWN<sub>2</sub> (P=8 and S=4)

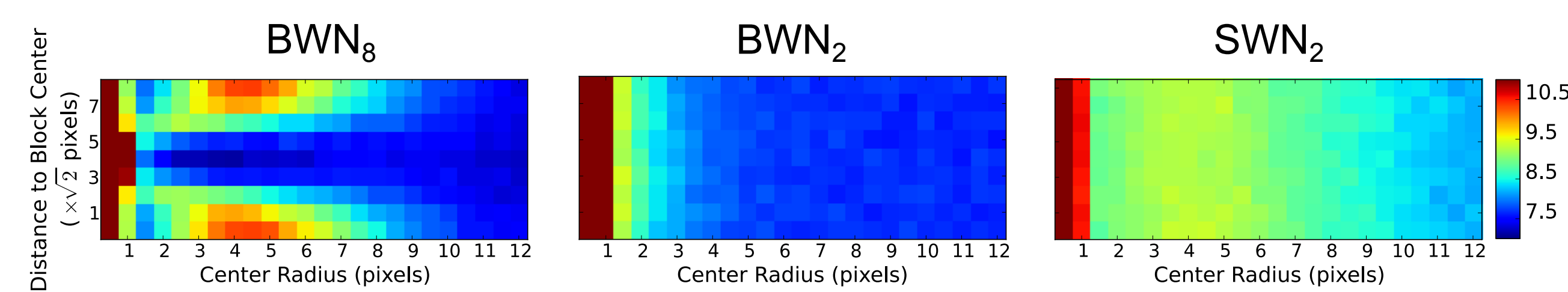
Neural Ensemble Model:

- Linear-Nonlinear Poisson (LNP) neurons
- Spatial RFs: Difference-of-Gaussians (DOG); Temporal RFs: 2 phases function
- DOG varying in position and size

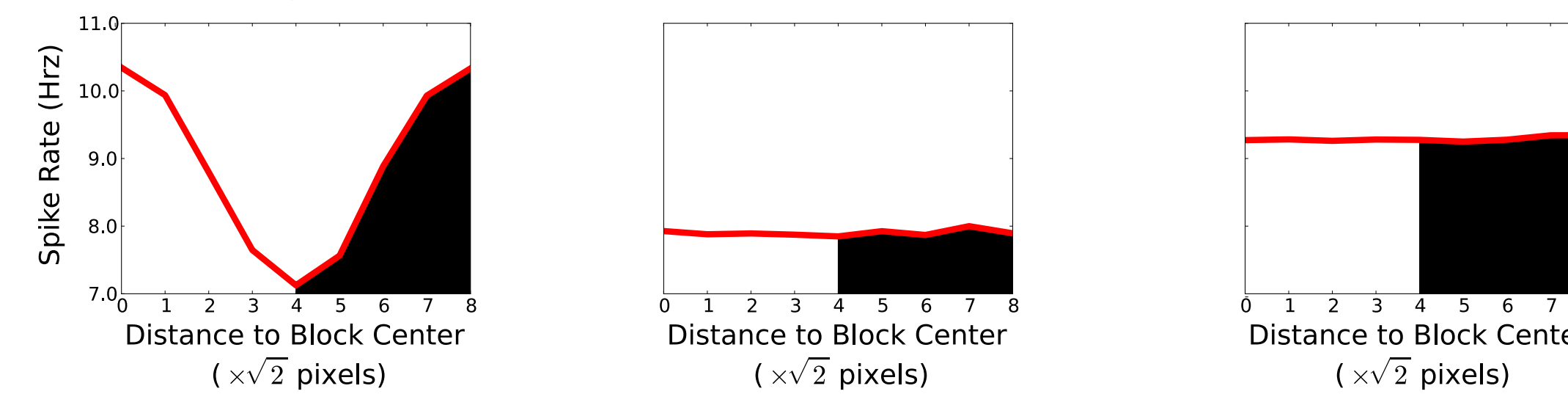


## RESULTS: AVERAGE SPIKE RATE

Neuron's spike rate as a function of RF position and size:



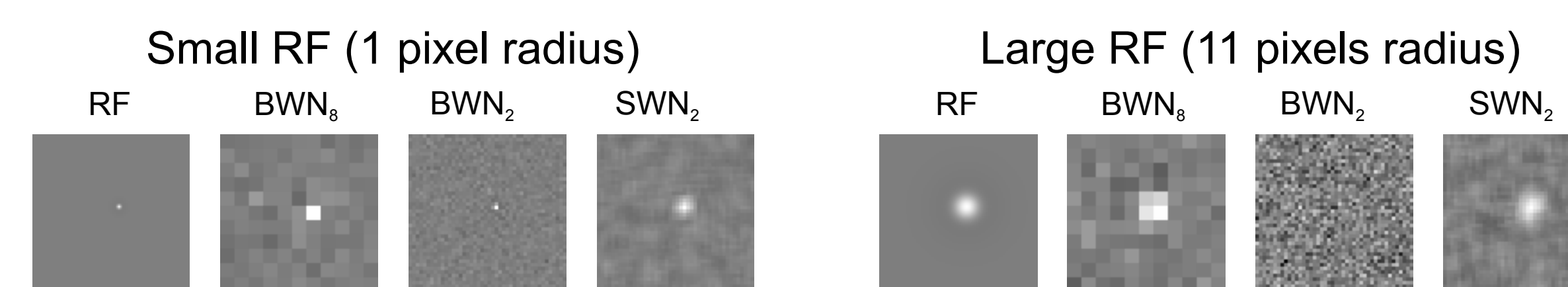
For a radius of 5 pixels:



Conclusion: Under the BWN<sub>2</sub> and SWN<sub>2</sub> the neuron's spike rate is independent on the RFs position, on the contrary BWN<sub>8</sub>'s spike rate is dependent on the position. In general, SWN<sub>2</sub> leads the highest spike rate and BWN<sub>2</sub> to the lowest one.

## RESULTS: SPIKE TRIGGERED AVERAGE

Spatial RF:



Profile on the x-axis:

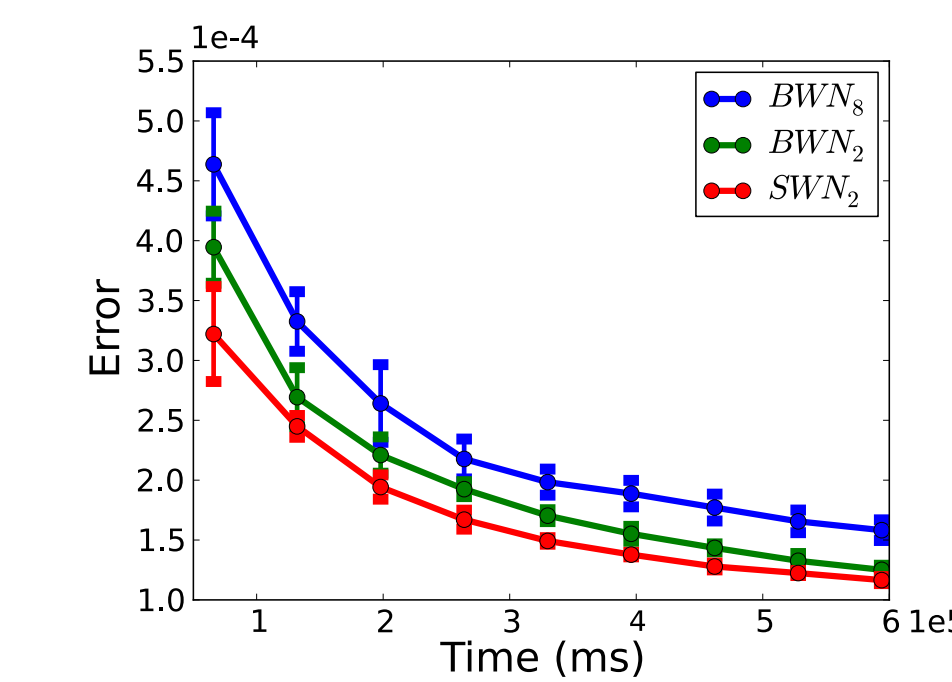


Conclusion: for a small RF the STA is better under SWN<sub>2</sub> than BWN<sub>8</sub>. For a large RF the SWN<sub>2</sub> is clearly the best.

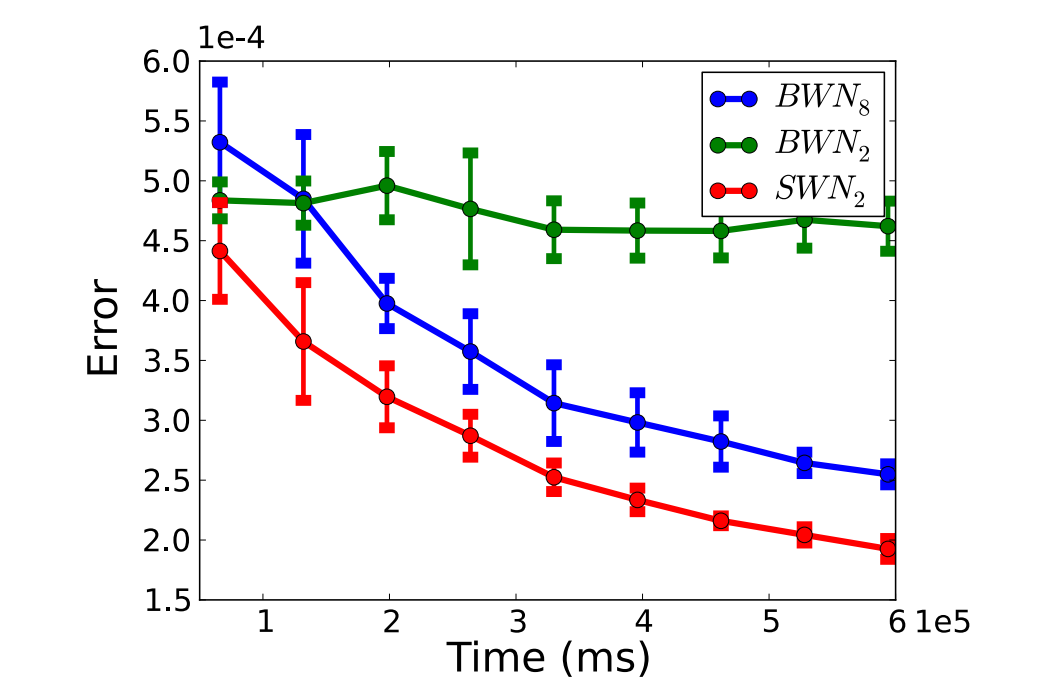
## RESULTS: CONVERGENCE SPEED

Small RF

STA error as a function of time:



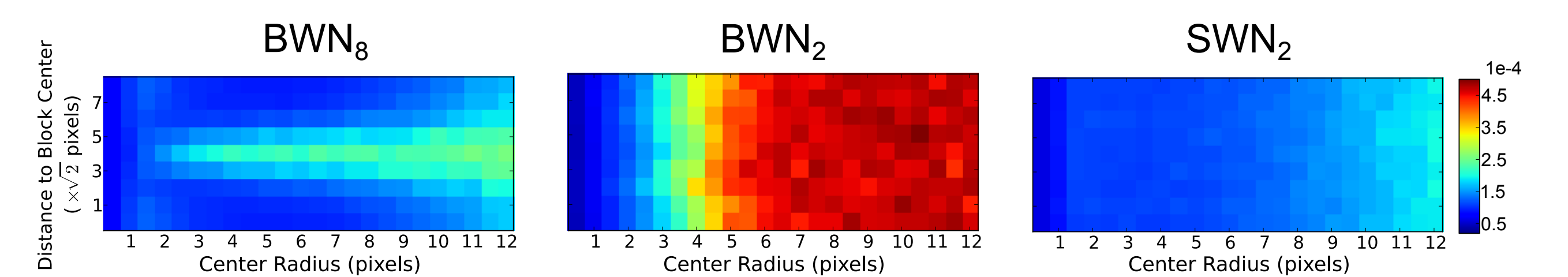
Large RF



Conclusion: For small RFs, given that the neuron's spike rate is similar under the three stimuli, the speed of convergence is similar. In contrary, for large RFs, the neuron's spike rate under BWN<sub>2</sub> stimulation is low, therefore the speed of convergence as well. In both cases, the SWN<sub>2</sub> converges as fast as BWN<sub>8</sub>.

## RESULTS: ESTIMATION ERROR

STA error as a function of the DOG position and size:



Conclusion: In general, the STA error is smaller under the SWN<sub>2</sub> than both BWN<sub>8</sub> and BWN<sub>2</sub>. Furthermore, under the SWN<sub>2</sub> the error does not depend on the position, but it depends slightly on the RF size.

## CONCLUSIONS

The shifted stimulus has the following properties:

- 1) For a fixed block size, the STA spatial resolution is improved as a function of the number of possible shifts, leading to smaller estimation error.
- 2) Targeting a given STA spatial resolution, shifting the stimulus increases the convergence speed.

This means that, for a fixed stimulation time, this method allows a global improvement in the estimation RFs independently of their characteristics. Thus, this shifted stimulus method is suitable to fastly and accurately estimate the RFs of large neural ensembles.

## REFERENCES

- Chichilnisky, E. J. (2001). A simple white noise analysis of neuronal light responses. *Network: Comput. Neural Syst.*  
Foldiak, P. (2001). Stimulus optimization in primary visual cortex. *Neurocomputing.*  
Machens, C. K. (2002). Adaptive sampling by information maximization. *Physical Review Letters.*  
MacKay, D. (1992). Information-based objective functions for active data selection. *Neural computation.*  
Paninski, L. (2003). Convergence properties of three spike-triggered analysis techniques. *Network: Comput. Neural Syst.*  
Schwartz, O. et al (2006). Spike-triggered neural characterization. *J. Vis.*

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