Spike-based computing and learning in brains, machines, and visual systems in particular

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GDR Biocomp – 04/06/2018

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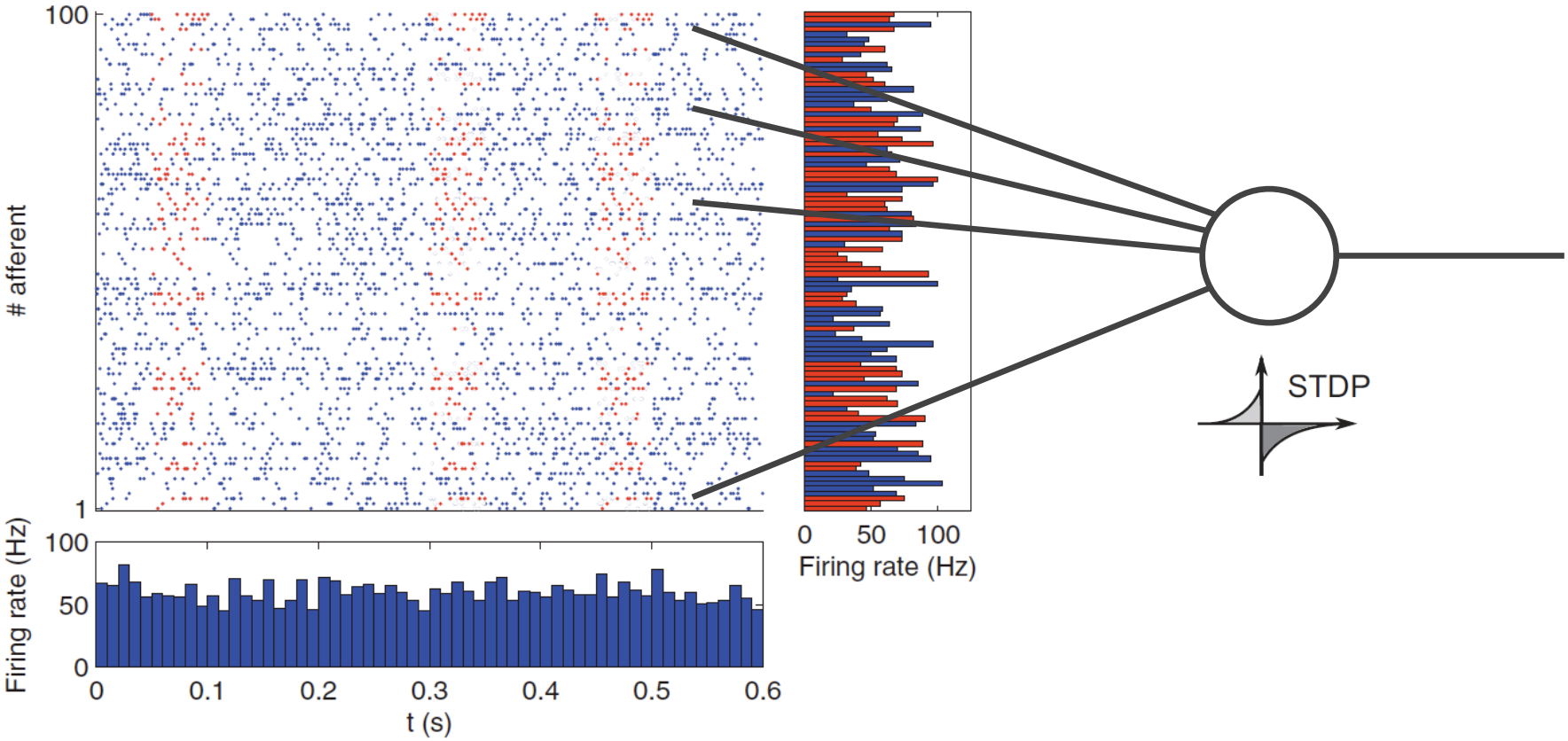
PLoS one

Spike Timing Dependent Plasticity Finds the Start of Repeating Patterns in Continuous Spike Trains

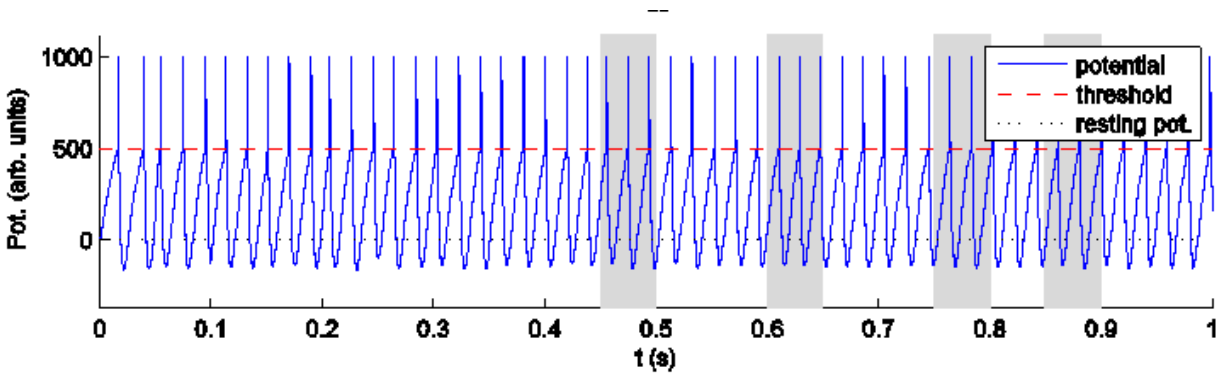
Timothée Masquelier[1,2]*, Rudy Guyonneau[1,2], Simon J. Thorpe[1,2]

January 2008 | Issue 1 | e1377

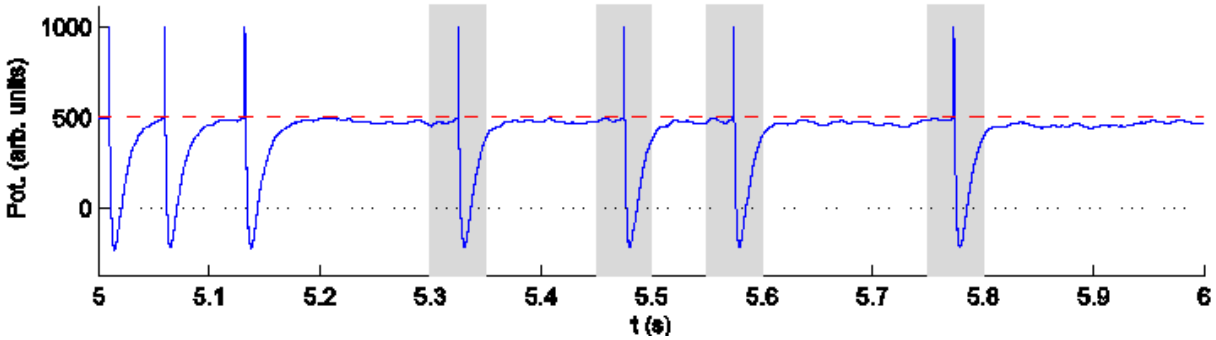


Results

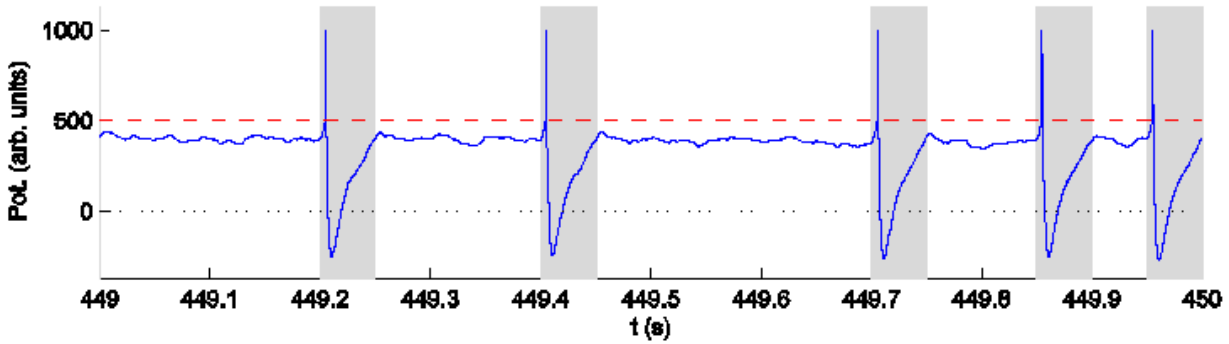
- Initial State



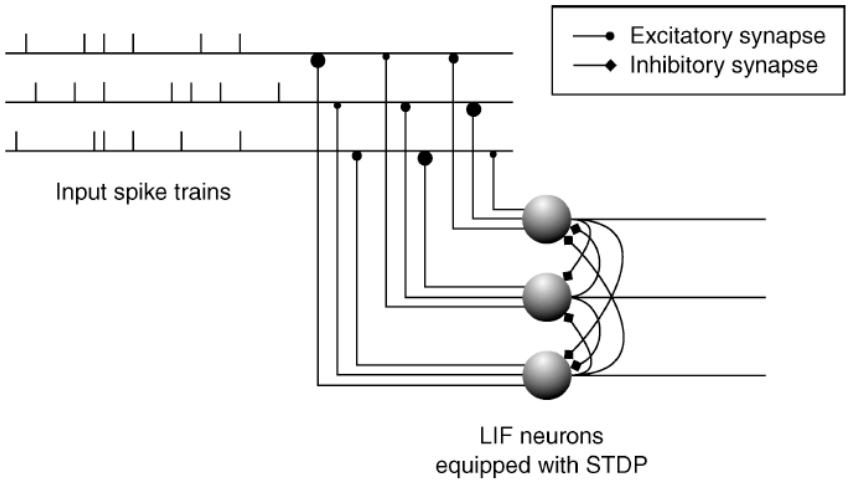
- During Learning



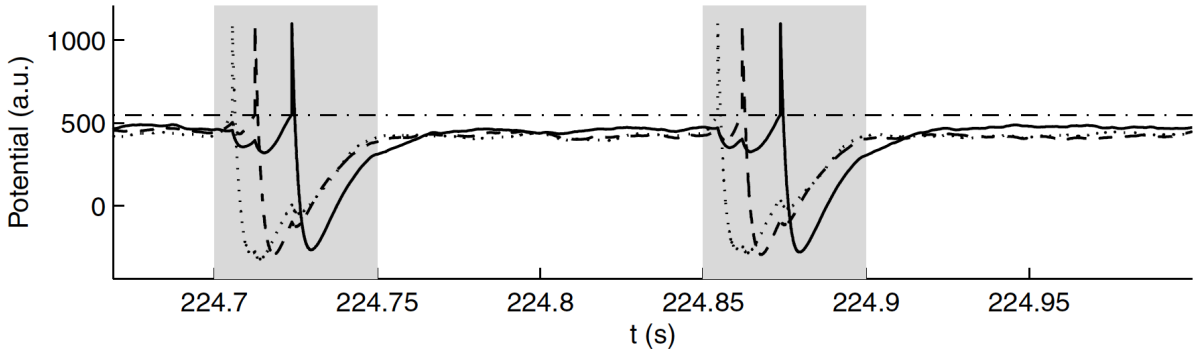
- After Learning



Learning the full pattern



Competitive learning



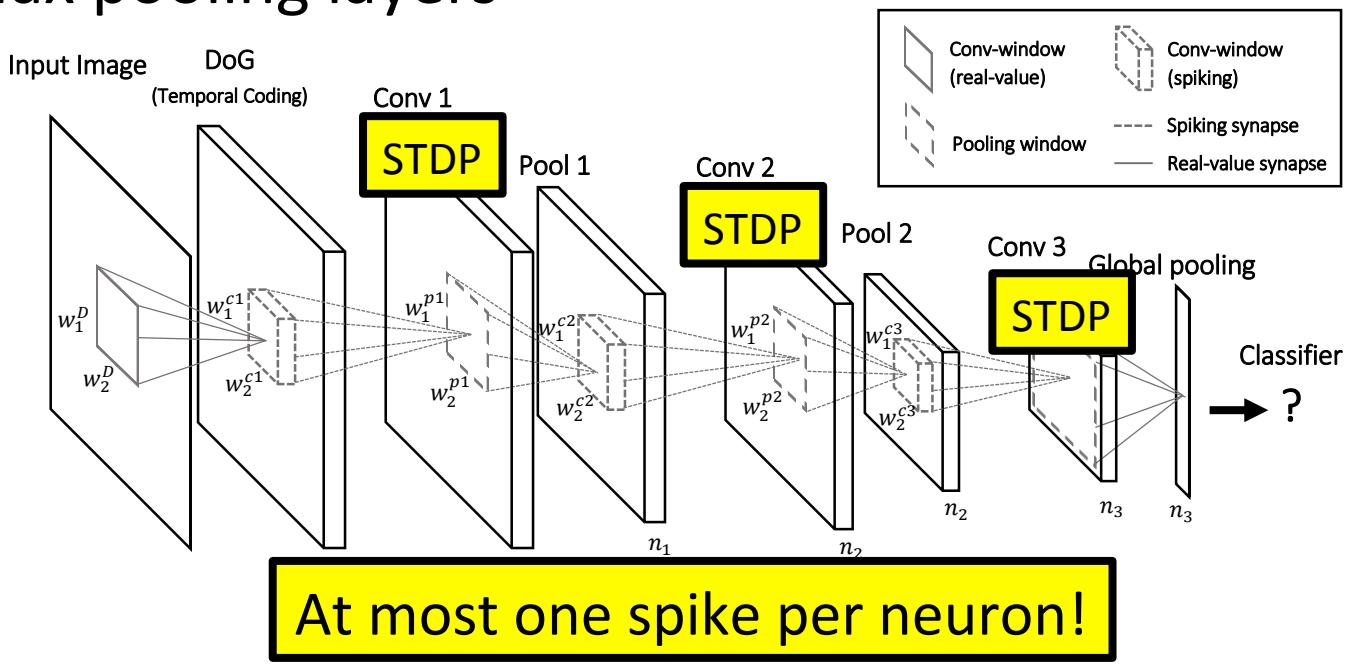
Neurons « stack »

Masquelier, Guyonneau & Thorpe 2009. Neural Comp

Models of the ventral stream of the visual cortex

- Feedforward
- Convolutional (weight sharing) layers
- Max pooling layers

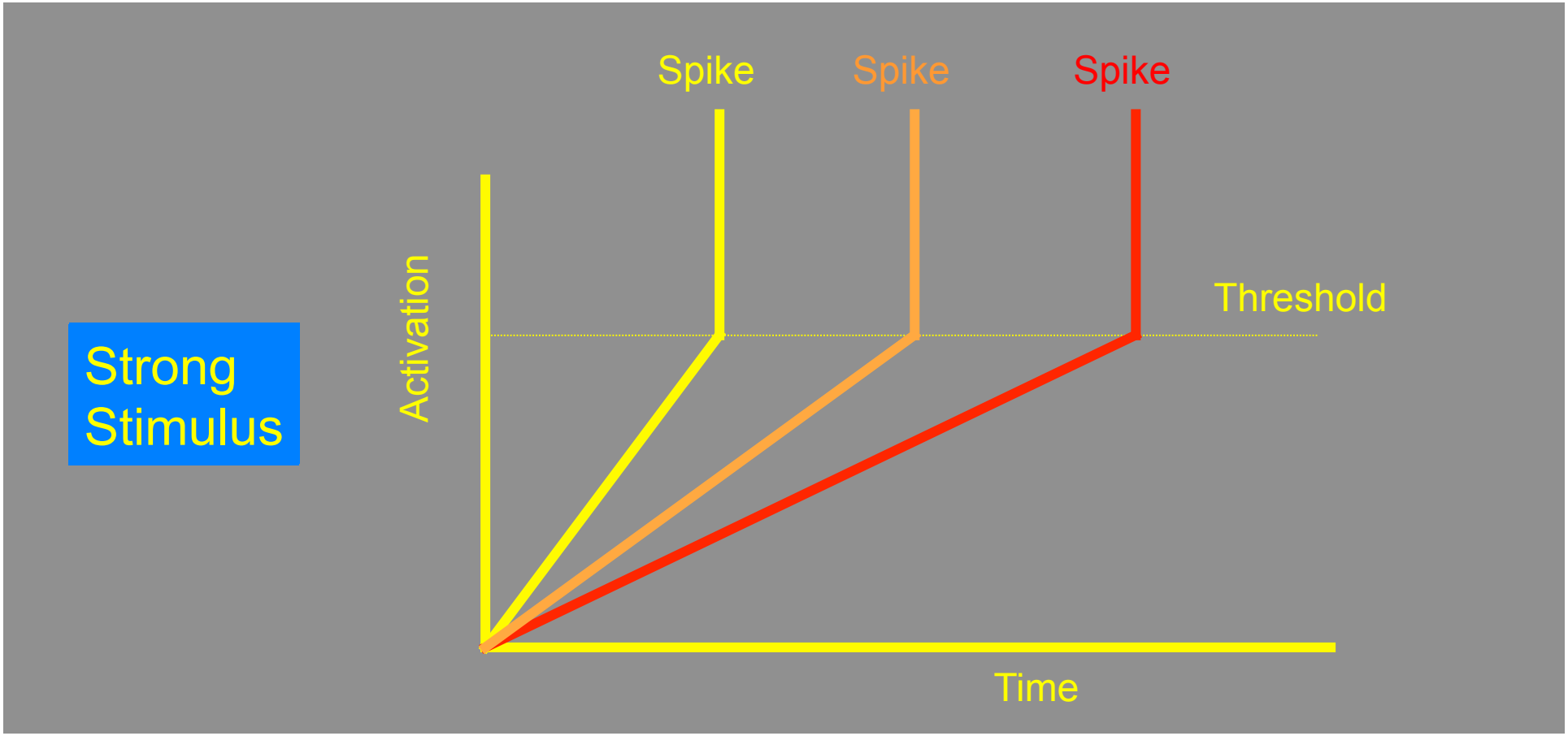
- Along the hierarchy
  - Selectivity increases
  - Invariance increases



At most one spike per neuron!

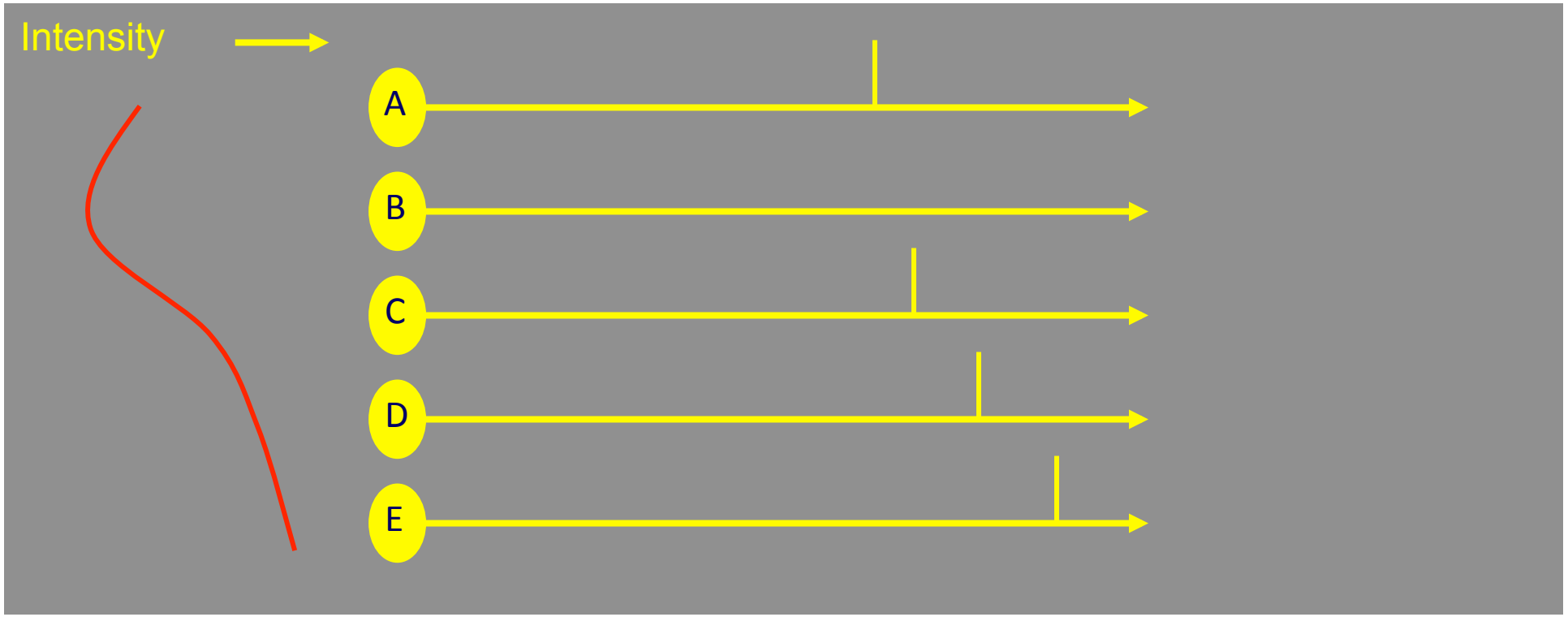
Fukushima, 1980; LeCun and Bengio, 1998; Riesenhuber and Poggio, 1999; Wallis and Rolls 1997; Rolls and Milward, 2000; Stringer and Rolls, 2000; Serre et al., 2007 + deep learning

First layer: intensity-to-latency conversion



≠ intensity-to-rate conversion (conventional view)

First layer: intensity-to-latency conversion



Spike waves

STDP-based deep feature extraction

Kheradpisheh, Ganjtabesh, Thorpe & Masquelier 2018. Neural Networks

Discussion

Technology:

Recognition performance does not match (yet?) deep learning but:

- Energy efficient (sparse coding)
- Hardware friendly
- STDP is a local rule
- Online, on-chip, learning
- (Mostly) unsupervised learning
- Only a few tens of labeled examples needed per category

Neuroscience:

Our proposal is compatible with

- The temporal constraints (object recognition is fast in primates)
- The fact that we learn mostly by observing the world, in an unsupervised way

Reward-modulated STDP (shallow net)

- Each neuron in the top layer is assigned to a category
- Latency-based category decisions
- Reward modulated STDP:
  - STDP if correct
  - Anti-STDP if wrong

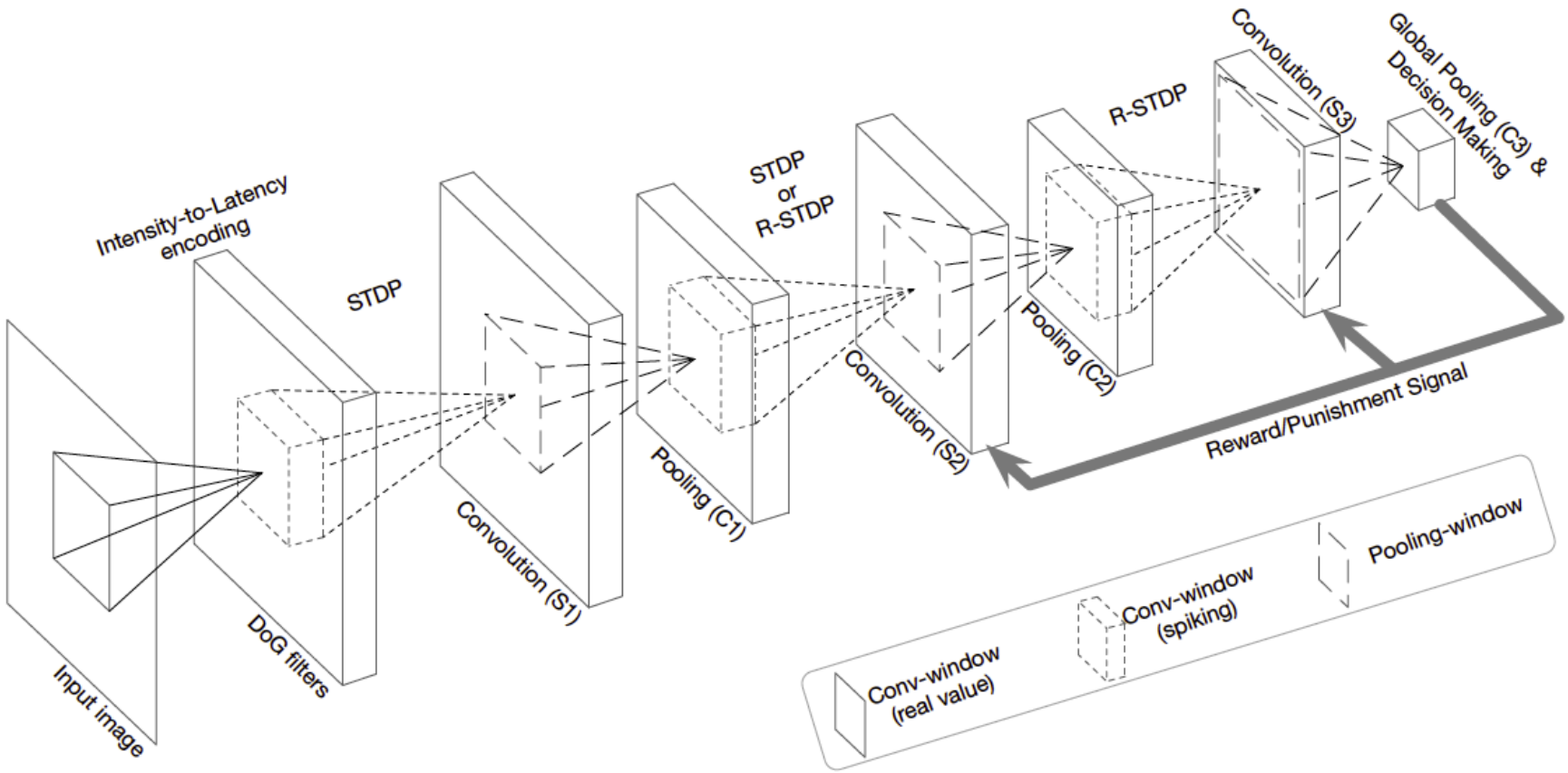
Advantages w.r.t. STDP:

- Extracts diagnostic features
- No external classifier
- “Semantic” neurons

Still biologically plausible, energy efficient, hardware friendly!

Mozafari, Kheradpisheh, Masquelier, Nowzari-Dalini & Ganjtabesh. IEEE TNNLS, in press

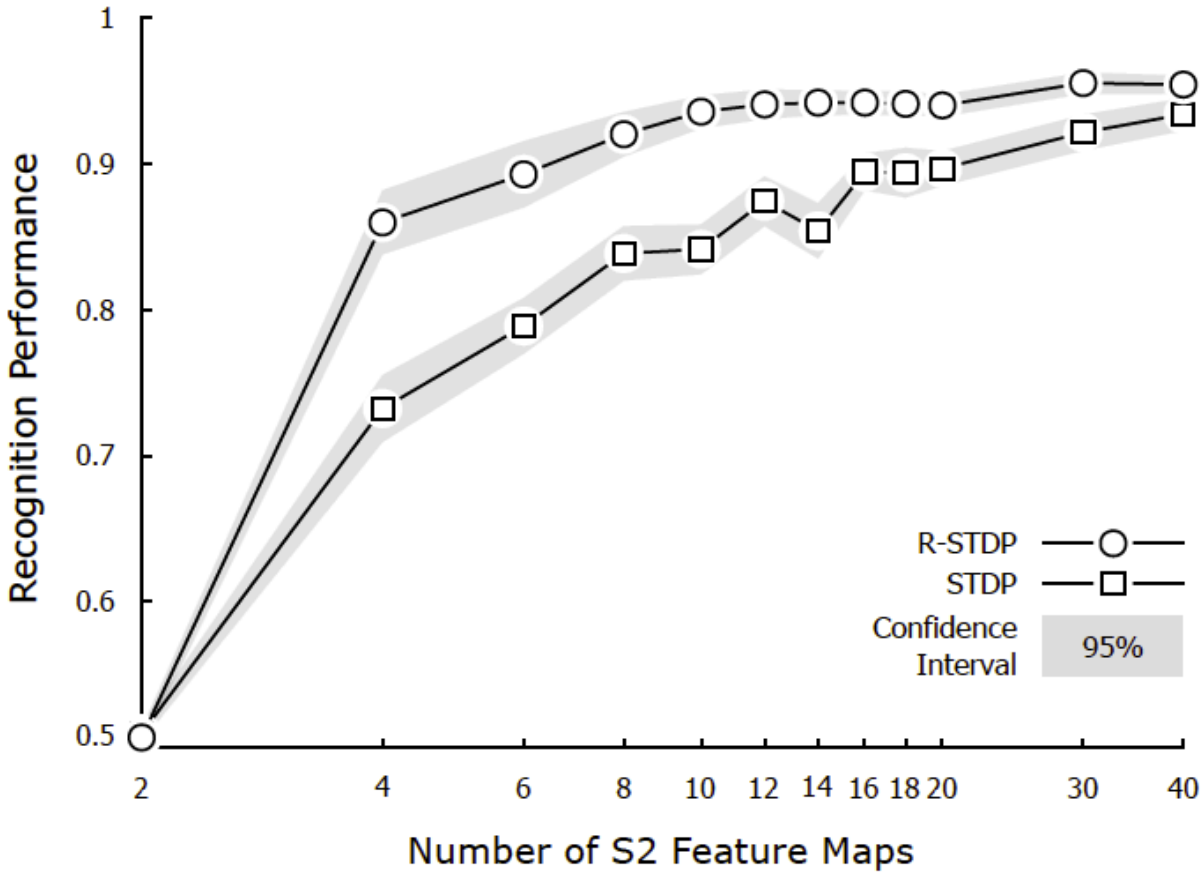
Deep reward-modulated STDP



97.2% correct on MNIST

Mozafari, Ganjtabesh, Nowzari-Dalini, Thorpe & Masquelier. arXiv 2018

RSTDP favors diagnostic features



Stay tuned: a pyTorch open source code is in preparation !!!

But normal vision is continuous

- No stimulus onset
- Thus no absolute latencies
- Yet we do (micro)saccades

www.nature.com/scientificreports

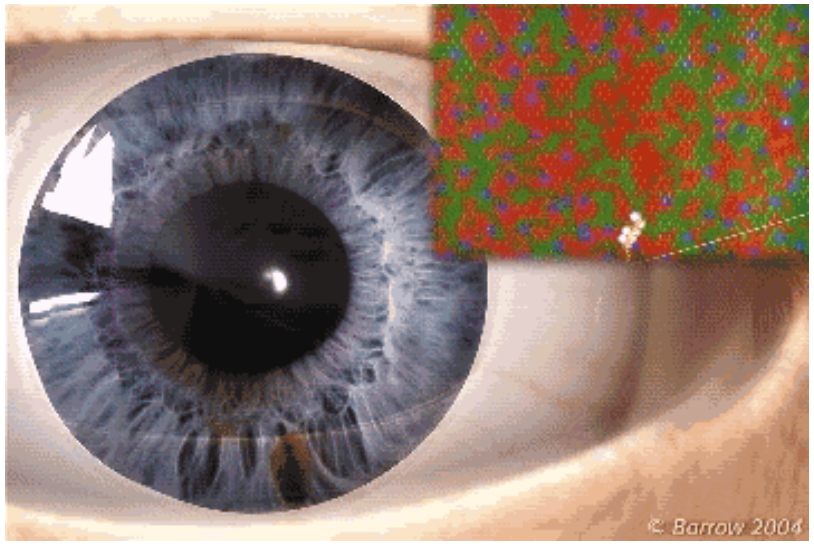
SCIENTIFIC REPORTS

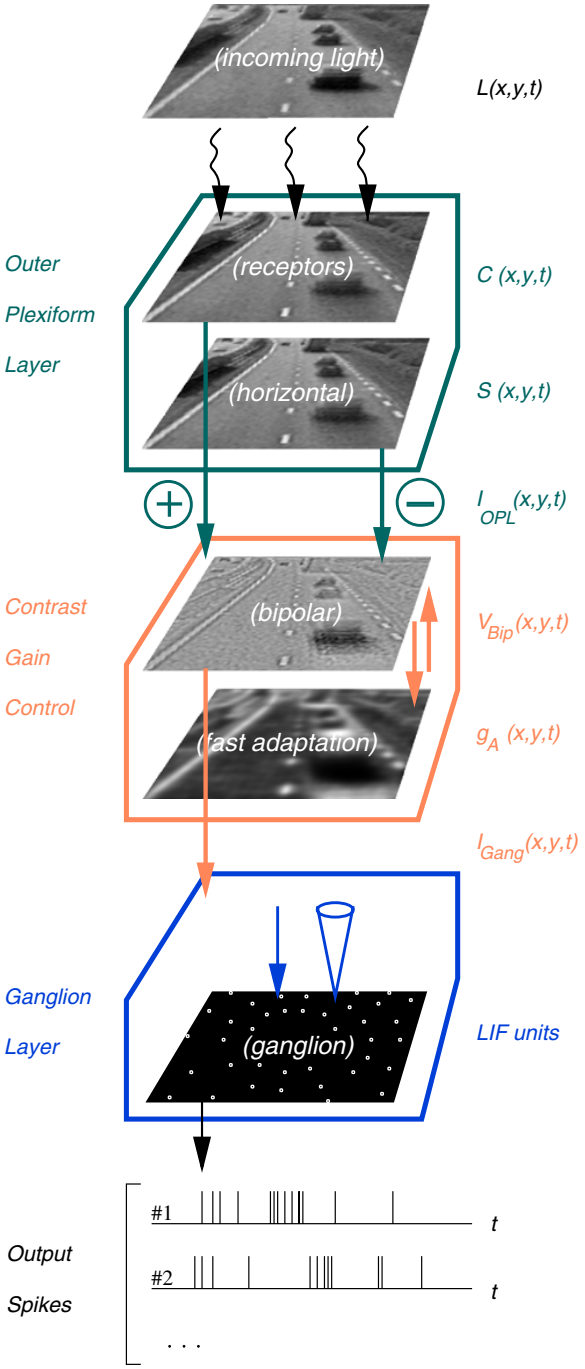
OPEN

Microsaccades enable efficient synchrony-based coding in the retina: a simulation study

Published: 11 April 2016

Timothée Masquelier[1,2,3,†], Geoffrey Portelli[4] & Pierre Kornprobst[4]





Virtual Retina

- Primate
- Foveal midget cells (parvocellular pathway, involved in fine vision)
- Spatiotemporal filtering (center-surround + sensitivity for changes)
- Strong transient (phasic) and weaker sustained (tonic) response
- RGC = Leaky Integrate-and-Fire
- White noise current

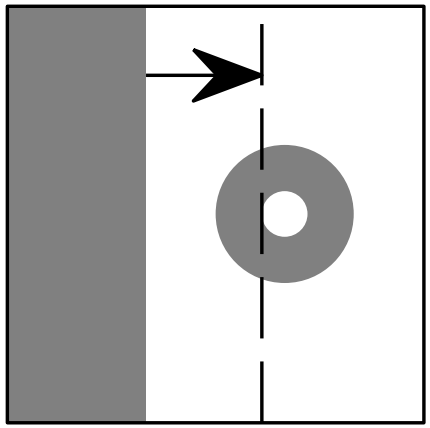
Wohrer & Kornprobpst 2009 J Comp Neurosc

Can saccadic motions generate synchronous firing?

Under what conditions?

A first simple scenario with moving edges.

Moving edges: speed



Speed:

2.5°/s
5°/s
10°/s
20°/s
∞

RGC input current:

Thr. current

PSTH:

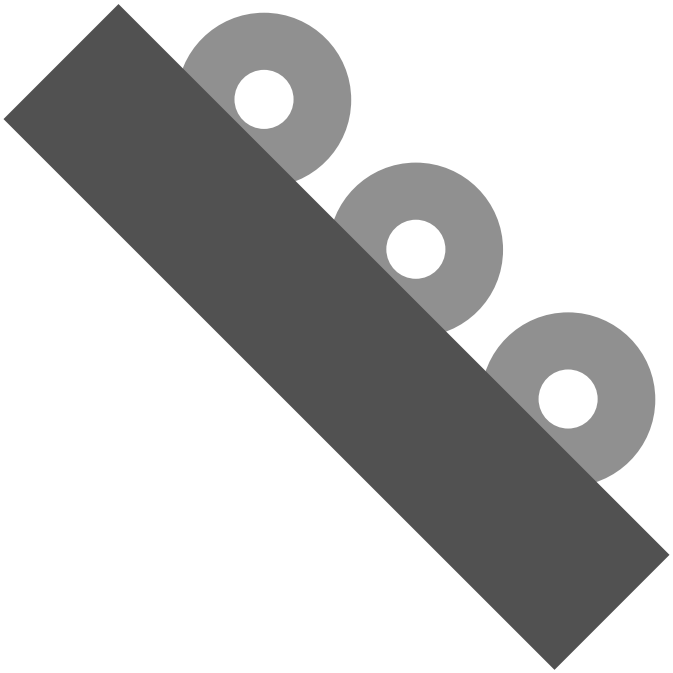
50ms

40Hz

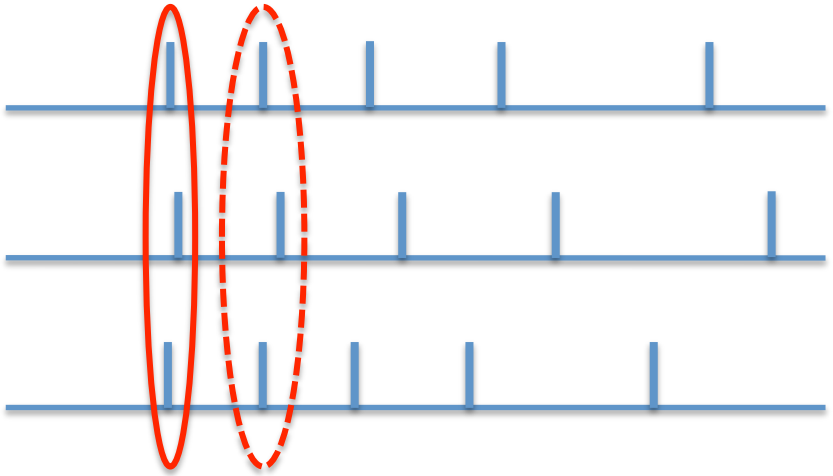
t=0 (motion stop)

=>rapidly moving contrasted edges cause synchronous firing

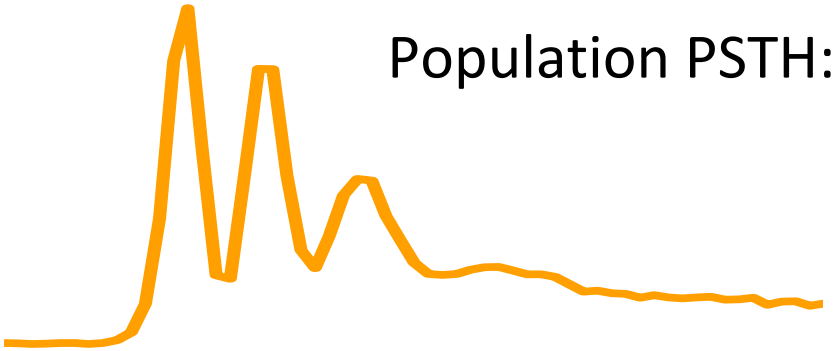
1 trial, multiple cells



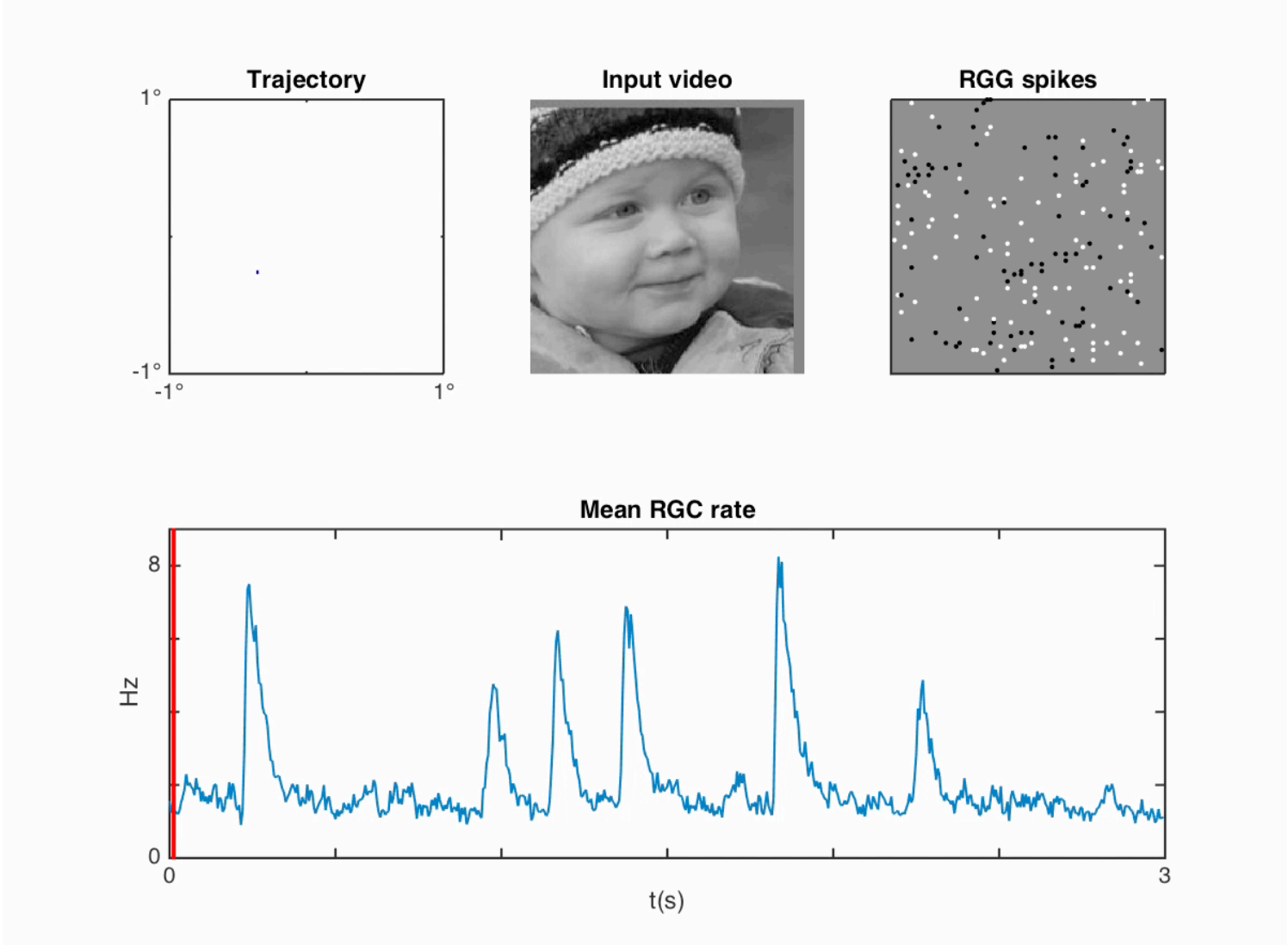
Population raster:



Population PSTH:



Natural images + realistic gaze trajectory

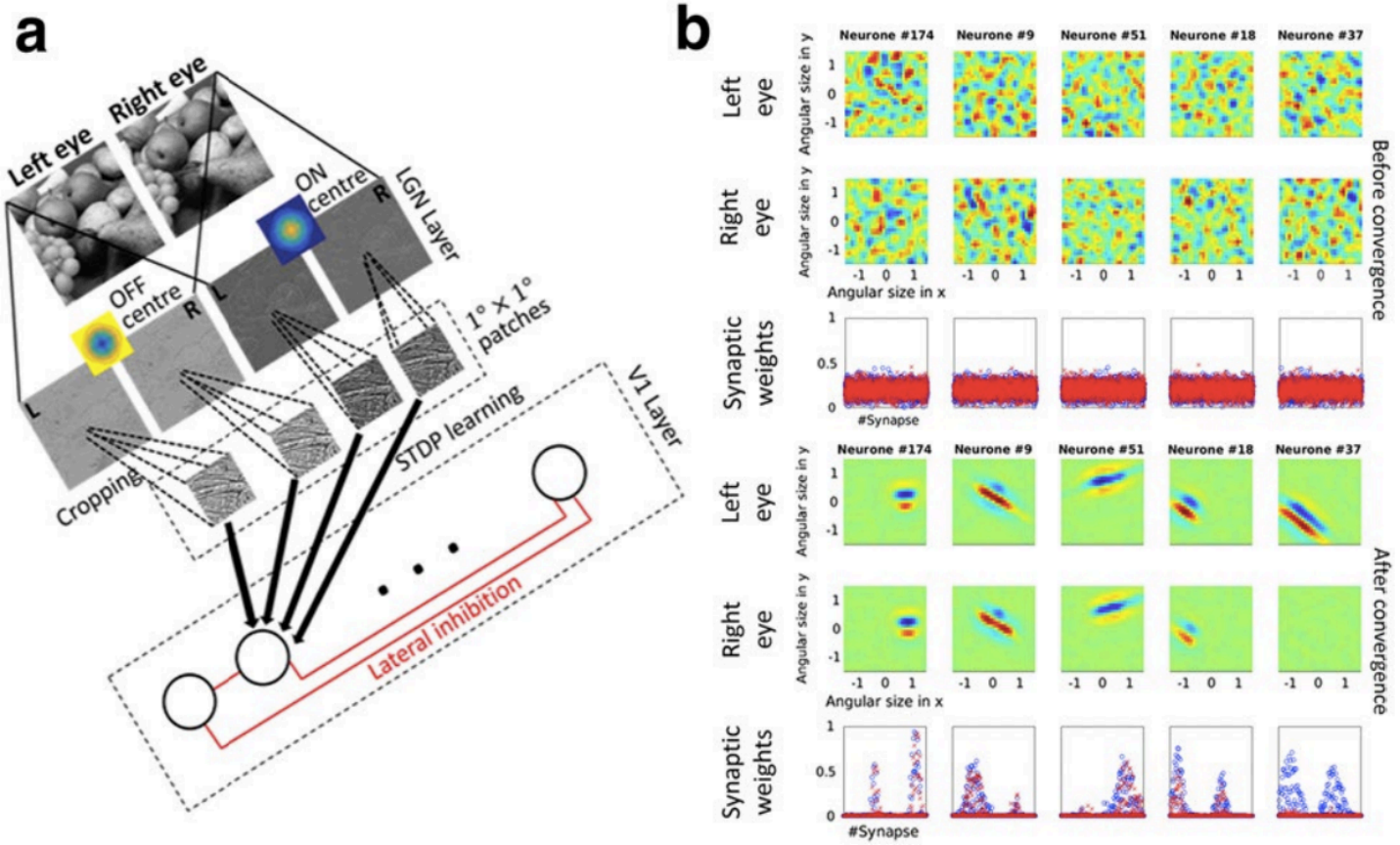


Discussion

- After each MS a volley of synchronous spikes transmits salient edges
- Readout is rapid and only needs coincidence detector neurons
- Required connectivity can emerge with STDP
- Could explain why we make more MS when paying attention to fine details.

A few on-going projects

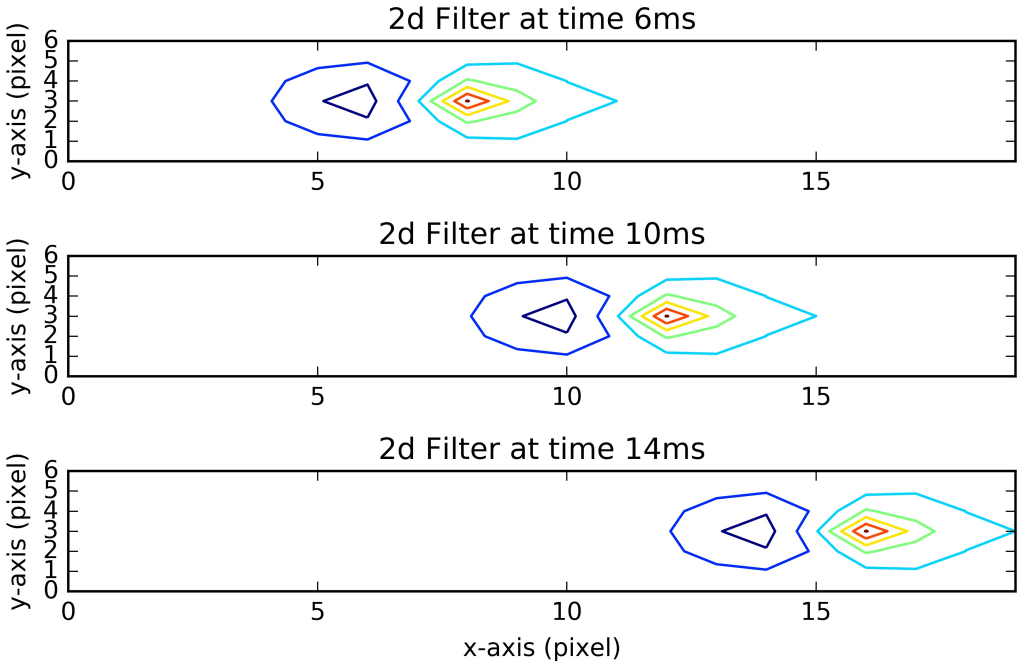
STDP for stereo vision



Chauhan, Masquelier, Montlibert & Cottereau. bioRxiv 2018

Convis: A Toolbox to Fit and Simulate Filter-Based Models of Early Visual Processing

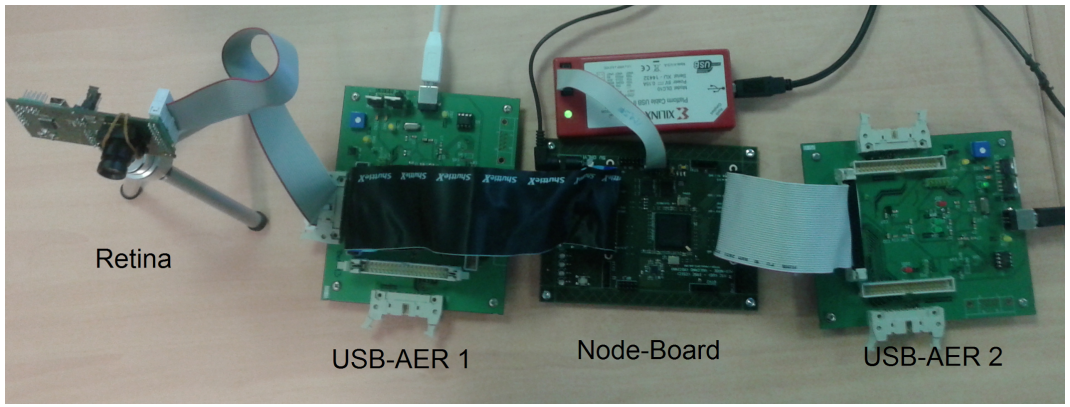
- A simulator for early visual system with arbitrary spatiotemporal receptive fields (unlike Virtual Retina) based on pyTorch
- Just-in-time optimization and compilation onto CPU or GPU architectures.
- Automatic differentiation facilitates model fitting



A direction selective cell

Huth, Masquelier & Arleo. Frontiers in Neuroinf. 2018

Neuromorphic engineering & tech transfer



CENTRO NACIONAL DE MICROELECTRÓNICA IMSE

Two patents submitted to the European Patent Office in November 2016 and February 2017 (application numbers EP16306525 and EP17305186).

brainchip

BrainChip Advances its Position as a Leading Artificial Intelligence Provider with an Exclusive License for Next-Generation Neural Network Technology

With Thorpe, Linares-Barranco, Yousefzadeh & Martin

Thanks to my main collaborators:

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