Neuronal population activity involved in motor patterns of the spinal cord:

Spiking regimes and skewed involvement

Rune W. Berg

University of Copenhagen Banff, Canada March 2017





<u>Lab</u>:

Peter Petersen Alex Willumsen Kristian Reveles Jensen Henrik Linden Qiaolin Xie Mikkel Vestergaard Marija Radosevic Jonas Villadsen Andrea Dietz Annemarie Horn

<u>Collaborators:</u>

Susanne Ditlevsen Patrick Jahn



Funding: Danish Research council Novo Nordisk Foundation

- Participation of neuron in behaviors
- Mechanism and Spiking regimes
- Connectivity of spinal networks

Understanding networks ?



Understanding networks ?



Division of labor



Understanding networks ?



Skewed distribution of power

Division of labor





Central Pattern Generators

Chewing, Swimming, scratching, breathing and walking

Decerebrate cat:



Whelan, Prog. Neurobiol 1996 MacKay-Lyons, Phys. Therap. 2002

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"Fictive locomotion" by adding neuro-chemicals



Goulding, Nat Rev Neurosci 2009

Model for motor pattern generation:

Turtle scratch reflex





Robertson & Stein, J. Physiol. 1988



Sensory-specific scratching



Turtle is upside-down performing hindlimb scratching

Recording Population activity

Peter Petersen



Recording Population activity

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Berg64-Probe by Neuronexus

www.neuronexus.com



8 shanks with 8 leads = 64 ch

Electrophysiology: Multichannel recording



Experimental Setup



Experimental Setup

Histology DiD-labeling and Nissle



Transverse section

Sagittal section

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Spike sorting Different units on same probe





Results

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Right Pocket scracth

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Population Distribution of Spike Rates



Population Distribution of Spike Rates



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Population Distribution of Spike Rates



"Lognormal"

Buzsaki & Mizuseki 2014

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Skewed distribution of power



Gini coefficient (measure of wealth inequality)



Most countries: Gini = 0.3-0.4

World: Gini = 0.7

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Left Pocket scracth

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Distribution of Spike Rates



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Reproducibility

Left pocket scratch

Right pocket scratch

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Petersen and Berg, in preparation



Petersen and Berg, in preparation



Petersen and Berg, in preparation







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Division of labor


Mechanism behind skewed distribution?

The Journal of Neuroscience, November 9, 2011 • 31(45):16217–16226 • 16217

Behavioral/Systems/Cognitive

On the Distribution of Firing Rates in Networks of Cortical Neurons

Alex Roxin,^{1,3} Nicolas Brunel,² David Hansel,^{2,4} Gianluigi Mongillo,² and Carl van Vreeswijk² ¹Center for Theoretical Neuroscience, Columbia University, New York, New York 10032, ²Centre National de la Recherche Scientifique, Unité Mixte de

Recherche 8119, Université Paris Descartes, 75270 Paris, France, ³Insitut d'Investigacions Biomèdiques August Pi i Sunyer, Barcelona 08036, Spain, and ⁴Interdisciplinary Center for Neural Computation, Hebrew University, 91904 Jerusalem, Israel

"We argue that skewed rate distributions are a signature of the nonlinearity of the in vivo F-I-curve"

Transformation of input-to-output



Input Current [nA]

Roxin et al, J Neurosci 2011

Transformation of input-to-output



Roxin et al, J Neurosci 2011





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Petersen and Berg, **eLife 2016** <u>www.berg-lab.net</u> ©

Skewness is rate dependent



Two regimes:

Fluctuation-driven

Mean-driven

Gerstner, Kistler, Naud and Paninski : "Neuronal dynamics"









Fluctuation- and mean-driven neurons



Driving a cell across regimes



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Driving a cell across regimes



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Driving a cell across regimes



Balanced E/I Unbalancing by blocking inhibition





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Single cell rate distribution







Next step: IO-curve Obtaining sub-threshold IO-curve is difficult



Patrick Jahn

FV-curve

expansive nonlinearity





Susanne Ditlevsen



Mikkel Vestergaard



Jahn et al **J Comput Neurosci 2011** Vestergaard and Berg, **J Neurosci 2015**

Input distribution?

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Inter-spike-interval Vm



Vm-distribution

sub-threshold



Vm-distribution

sub-threshold



Vm-distribution

sub-threshold





Mini-conclusion

- Firing rate distribution is skewed for some neurons
- Subthreshold IO curve is non-linear
- Input distribution is Gaussian

Spiking regime: population

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Spiking regime: population

 $CV_2 > 0.5$ "Irregular" $CV_2 < 0.5$ "Regular"

Young et al, J Neurophysiol 1988

Prut and Perlmutter, J Neurosci 2003







Cell type ?



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Cell type ?





Arber Neuron 2012

Cell type ?





Arber Neuron 2012





No dependence on cell type



Petersen and Berg, eLife 2016

Conclusions

- Skewed, log-normal firing rate distribution
- Conservation of position in distribution



Two regimes: fluctuation- and mean driven ~ 50%,
i.e. half of cells are in irregular regime half of the time.



Connectivity ?



Radosevic et al, in preparation 2017
Feedforward model



Radosevic et al, in preparation 2017

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Pairwise correlation slow and fast timescales



Radosevic et al, in preparation 2017

Pairwise recording



Radosevic et al, in preparation 2017

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Weak fast correlation





Radosevic et al, in preparation 2017

Feedforward model



Radosevic et al, in preparation 2017

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Sparse vs. dense



Radosevic et al, in preparation 2017

Conclusion

Lack of correlation in synaptic input Sparse and large network "Active desynchronization"

Radosevic et al, in preparation 2017

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<u>Lab</u>:

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Funding: Danish Research council Novo Nordisk Foundation

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