Lubomir Kostal

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Research Interests

- Mathematical modeling of biological neural systems:
  – Applications of information theory and estimation theory to computational neuroscience
  – Energetic cost of information coding in single neurons and populations
  – Signal processing in insect sensory (olfactory) system
- Statistical measures of variability of stochastic processes

Affiliation and Positions

2014 – **Group leader**: Laboratory of Computational Neuroscience, Institute of Physiology
2011–2013 Associated scientist, Institute of Physiology
2007–2010 Postdoc
2004–2007 PhD student, Institute of Physiology and Charles University Prague
2004 Assistant at the Department of Neurophysiology of Memory and Computational Neuroscience, Institute of Physiology

Visiting and Temporal Positions

Long-term stay in the lab of Prof. Jean-Pierre Rospars, INRA, Versailles, France (doctoral and postdoc stay, intermittently **2005–2010**), team member in the projects: Barrande and ECO-NET 12644PF.

Education

2007 PhD (biophysics), Charles University Prague and Institute of Physiology,
Thesis: "Principles of information processing in neuronal models".
2003 MSc (physics), Faculty of Mathematics and Physics, Charles University Prague.

Awards

- 2017: Prize for the best paper (Institute of Physiology, CAS): Rajdl K, Lansky P, Kostal L (2017) Entropy factor for randomness quantification in neuronal data. *Neural Netw.*, **95**, 57–65.
- 2012: *Otto Wichterle Award*[1] by the Czech Academy of Sciences: "To stimulate and encourage selected, exceptionally outstanding, promising young scientists for their remarkable contributions to the advancement of scientific knowledge in a given area of science."
- 2011: Prize for the best paper (Institute of Physiology, CAS): Kostal L, Lansky P Pokora O (2011) Variability measures of positive random variables. *PLoS ONE*, **6**, e21998.
- 2010: Best poster presentation award (Kostal L: "Information capacity in the weak-signal approximation"), *Neural Coding 2010*, Limassol, Cyprus.
- 1997: *Students' Professional Activities (SPA)*: Winner of the nation-wide high-school student competition in Physics with the thesis: "Numerical solution of the geodesic equation in general relativity for the extreme Schwarzschild-de Sitter metric" (supervisor: Prof. J. Podolsky, Faculty of Mathematics and Physics, Charles University Prague).

[1] Detailed description:
https://www.avcr.cz/en/academic-public/support-of-research/otto-wichterle-award/

Publications in Journals[2]

∗ 41. Barta, T.✉& Kostal, L.✉ (2024) Shared input and recurrency in neural networks for metabolically efficient information transmission. *PLoS Comput. Biol.*, **20**, e1011896.

∗ 40. Rajdl, K.✉& Kostal, L. (2023) Estimation of the instantaneous spike train variability. *Chaos Solit. Fractals*, **177**, 114280.

39. Lee, H., Kostal, L., Kanzaki, R. & Kobayashi, R.✉ (2023) Spike frequency adaptation facilitates the encoding of input gradient in insect olfactory projection neurons. *Biosystems*, **223**, 104802.

38. Tomar, R.✉& Kostal, L. (2021) Variability and Randomness of the Instantaneous Firing Rate. *Front. Comput. Neurosci.*, **15**, 620410.

37. Barta, T.✉& Kostal, L. (2021) Regular spiking in high conductance states: The essential role of inhibition. *Phys. Rev. E*, **103**, 022408.

36. Rajdl, K.✉, Lansky, P. & Kostal, L. (2020) Fano factor: a potentially useful information. *Front. Comput. Neurosci.*, **14**, 569049.

35. Ascione, G., D'Onofrio, G., Kostal, L. & Pirozzi, E.✉ (2020) An optimal Gauss-Markov approximation for a process with stochastic drift and applications. *Stoch. Proc. Appl.*, **130**, 6481–6514.

∗ 34. Barta, T.✉& Kostal, L. (2019) The effect of inhibition on rate code efficiency indicators. *PLoS Comput. Biol.*, **15**, e1007545.

∗ 33. Kostal, L.✉& Kobayashi, R. (2019) Critical size of neural population for reliable information transmission. *Phys. Rev. E (Rapid Commun.)*, **100**, 050401(R).

32. Levakova, M.✉, Kostal, L., Monsempès, C., Lucas, P. & Kobayashi, R. (2019) Adaptive integrate-and-fire model reproduces the dynamics of olfactory receptor neuron responses in moth. *J. R. Soc. Interface*, **16**, 20190246.

∗ 31. Levakova, M.✉, Kostal, L., Monsempès, C., Jacob, V. & Lucas, P. (2018) Moth olfactory receptor neurons adjust their encoding efficiency to temporal statistics of pheromone fluctuations. *PLoS Comput. Biol.*, **14**, e1006586.

∗ 30. Kostal, L.✉, Lansky, P. & Stiber, M. (2018) Statistics of inverse interspike intervals: the instantaneous firing rate revisited. *Chaos*, **28**, 106305.

29. Kostal, L.✉& D'Onofrio, G. (2018) Coordinate invariance as a fundamental constraint on the form of stimulus-specific information measures. *Biol. Cybern.*, **112**, 13–23.

∗ 28. Rajdl, K.✉, Lansky, P. & Kostal, L. (2017) Entropy factor for randomness quantification in neuronal data. *Neural Netw.*, **95**, 57–65.

27. Levakova, M.✉, Tamborrino, M., Kostal, L. & Lansky, P. (2017) Accuracy of rate coding: When shorter time window and higher spontaneous activity help. *Phys. Rev. E*, **95**, 022310.

26. Levakova, M.✉, Tamborrino, M., Kostal, L. & Lansky, P. (2016) Presynaptic spontaneous activity enhances the accuracy of latency coding. *Neural Comput.*, **28**, 2162–2180.

∗ 25. Kostal, L.✉ (2016) Stimulus reference frame and neural coding precision. *J. Math. Psychol.*, **71**, 22–27.

24. Kostal, L.✉& Lansky, P. (2016) Coding accuracy on the psychophysical scale. *Sci. Rep.*, **6**, 23810.

23. Kostal, L.✉& Shinomoto, S. (2016) Efficient information transfer by Poisson neurons. *Math. Biosci. Eng.*, **13**, 509–520.

22. Kostal, L.✉& Kobayashi, R. (2015) Optimal decoding and information transmission in Hodgkin-Huxley neurons under metabolic cost constraints. *BioSystems*, **136**, 3–10.

∗ 21. Kostal, L.✉, Lansky, P. & Pilarski, S. (2015) Performance breakdown in optimal stimulus decoding. *J. Neural Eng.*, **12**, 036012.

20. Kostal, L.✉& Lansky, P. (2015) Coding accuracy is not fully determined by the neuronal model. *Neural Comput.*, **27**, 1051–1057.

19. Koyama, S.✉& Kostal, L. (2014) The effect of interspike interval statistics on the information gain under the rate coding hypothesis. *Math. Biosci. Eng.*, **11**, 63–80.

∗ 18. Kostal, L.✉, Lansky, P. & Pokora, O. (2013) Measures of statistical dispersion based on Shannon and Fisher information concepts. *Inform. Sciences*, **235**, 214–223.

17. Kostal, L.✉& Lansky, P. (2013) Information capacity and its approximations under metabolic cost in a simple homogeneous population of neurons. *BioSystems*, **112**, 265–275.

[2]Representative publications marked with '∗'.

16. Kostal, L.✉, Lansky, P. & McDonnell, M. D. (2013) Metabolic cost of neuronal information in an empirical stimulus-response model. *Biol. Cybern.*, **107**, 355–365.
15. Kostal, L. & Pokora, O.✉ (2012) Nonparametric estimation of information-based measures of statistical dispersion. *Entropy*, **14**, 1221–1233.
14. Kostal, L.✉ (2012) Approximate information capacity of the perfect integrate-and-fire neuron using the temporal code. *Brain Res.*, **1434**, 136–141.
13. Kostal, L.✉, Lansky, P. & Pokora, O. (2011) Variability measures of positive random variables. *PLoS ONE*, **6**, e21998.
∗ 12. Kostal, L.✉ (2010) Information capacity in the weak-signal approximation. *Phys. Rev. E*, **82**, 026115.
11. Kostal, L.✉& Marsalek, P. (2010) Neuronal jitter: can we measure the spike timing dispersion differently? *Chin. J. Physiol.*, **53**, 454–464.
10. Kostal, L.✉& Lansky, P. (2010) Information transfer with small-amplitude signals. *Phys. Rev. E (Rapid Commun.)*, **81**, 050901(R).
9. Kostal, L.✉& Lansky, P. (2008) Randomness of spontaneous activity and information transfer in neurons. *Physiol. Res.*, **57**, S133–S138.
∗ 8. Kostal, L., Lansky, P. & Rospars, J.-P.✉ (2008) Efficient olfactory coding in the pheromone receptor neuron of a moth. *PLoS Comput. Biol.*, **4**, e1000053.
7. Kostal, L.✉, Lansky, P. & Rospars, J.-P. (2007) Encoding of pheromone intensity by dynamic activation of pheromone receptors. *Neurocomputing*, **70**, 1759–1763.
∗ 6. Kostal, L.✉, Lansky, P. & Rospars, J.-P. (2007) Review: Neuronal coding and spiking randomness. *Eur. J. Neurosci.*, **26**, 2693–2701.
5. Kostal, L.✉& Lansky, P. (2007) Variability and randomness in stationary neuronal activity. *BioSystems*, **89**, 44–49.
4. Kostal, L.✉, Lansky, P. & Zucca, C. (2007) Randomness and variability of the neuronal activity described by the Ornstein-Uhlenbeck model. *Netw. Comput. Neural Syst.*, **18**, 63–75.
3. Kostal, L.✉& Lansky, P. (2006) Classification of stationary neuronal activity according to its information rate. *Netw. Comput. Neural Syst.*, **17**, 193–210.
2. Kostal, L.✉& Lansky, P. (2006) Similarity of interspike interval distributions and information gain in a stationary neuronal firing. *Biol. Cybern.*, **94**, 157–167.
1. Duchamp-Viret, P., Kostal, L., Chaput, M., Lansky, P. & Rospars, J.-P.✉ (2005) Patterns of spontaneous activity in single rat olfactory receptor neurons are different in normally breathing and tracheotomized animals. *J. Neurobiol.*, **65**, 97–114.

Web of Science: 433 citations, h-index: 12
Google Scholar: 676 citations, h-index: 16

Publications in Books and Peer-reviewed Proceedings, Editorials

5. Christodoulou, C., Kostal, L. & Sacerdote, L. (2020) Editorial, Special issue of BioSystems on Selected papers presented at the Thirteenth International Workshop on Neural Coding, Torino, Italy, 2018. *BioSystems*, **187**, 104049.
4. Kostal, L., Sacerdote, L. & Tamborrino, M. (2019) Special Issue: Neural Coding 2018. *Math. Biosci. Eng.*, **16**, 8214–8216.
3. Christodoulou, C.✉, Kostal, L. & Büschges, A. (2017) Editorial, Special issue of BioSystems on Selected papers presented at the Twelveth International Workshop on Neural Coding, Cologne, Germany, 2016. *BioSystems*, **161**, 1–2.
2. Kostal, L.✉, Lansky, P. & Pokora, O. (2012) How regular is neuronal activity? In *ESANN 2012: The 20th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning*. ESANN, Bruges, Belgium, pp. 495–500.
1. Kostal, L.✉, Lansky, P. & Rospars, J.-P. (2008) The Adaptation of the Moth Pheromone Receptor Neuron to its Natural Stimulus. In Ricciardi, L., Buonocore, A. & Pirozzi, E. (eds.), *AIP Conference Proceedings, Collective Dynamics: Topics on Competition and Cooperation in the Biosciences: A Selection of Papers in the Proceedings of the BIOCOMP2007 International Conference*. AIP, Melville, New York, pp. 147–161.

Invited Talks[3]

2023 *Workshop on Stochastic Models of the Brain and related Topics*, University of Torino, Italy
2023 Lecture at the University of Tokyo, Kashiwa, Japan
2019 Lecture at the National Institute of Informatics, Tokyo, Japan
2017 Lecture at the University of Naples Federico II, Naples, Italy
2016 Lecture at the Institute for Stochastics, Johannes Kepler University, Linz, Austria
2016 *Workshop on multitrack event-trains in neural, social, seismological, and financial data*, Karuzaiwa, Japan
2014 *Biological and Bio-Inspired Information Theory*, Banff International Research Station, Canada
2014 *Mathematical Modeling and Statistical Analysis in Neuroscience*, University of Copenhagen, Denmark
2014 Lecture at RIKEN, Tokyo, Japan
2014 Lecture at the National Institute of Informatics, Tokyo, Japan
2013 *Matematické modely a aplikace*, Podlesí, Czech Republic
2013 CNS 2013 *Workshop on Methods of Information Theory in Computational Neuroscience*, Paris, France
2013 Workshop on the *Applications of Information Theory*, Ritsumeikan University, Japan
2013 Lecture at the Kyoto University, Japan
2009 *Workshop on Sensory Neuroinformatics*, Pilsen, Czech Republic

External Funding (Grants and Fellowships)

2024–2026 *Polymer memristor with neurosynaptic properties*, The Czech Science Foundation (GACR), principal co-investigator (≈ 41 086 EUR)
2022–2026 *Breakthrough Technologies for the Future – Sensing, Digitisation, Artificial Intelligence and Quantum Technologies*, Strategy AV21 (Czech Academy of Sciences), team member
2020–2022 *Optimality of neuronal communication: an information-theoretic perspective*, The Czech Science Foundation (GACR), principal investigator (≈ 309 480 EUR)
2020–2022 *Stochastic Models and Methods for the Study of Olfaction*, International project between Austrian FWF and GACR, principal investigator (≈ 240 640 EUR)
2019–2020 *Stochastic models and methods for the study of neuronal coding in the olfactory system*, Project MOBILITY (The Czech Republic and France), principal investigator (≈ 7 520 EUR)
2017–2018 *Neural coding in the moth olfactory sensory system*, Project MOBILITY (The Czech Republic and France), principal investigator (≈ 7 880 EUR)
2017–2019 *Neural coding precision and its adaptation to the stimulus statistics*, The Czech Science Foundation (GACR), principal investigator (≈ 218 800 EUR)
2017–2018 *Perturbed stochastic point processes as a novel tool for neural coding analysis*, Project MOBILITY (The Czech Republic and Austria), team member (≈ 8 340 EUR)
2015–2017 *Efficiency of information transfer and the role of energetic constraints in neuronal systems*, The Czech Science Foundation (GACR), principal investigator (≈ 264 000 EUR)
2015–2016 *Statistical inference for perturbed stochastic processes with applications to neuroscience*, Project MOBILITY (The Czech Republic and Austria), team member (≈ 8 000 EUR)
2012–2013 *Information beyond Shannon*, European Office of Aerospace Research and Development, support for the Information Beyond Shannon 2013 workshop, principal investigator
2012–2014 *Information-theoretic analysis of stimulus coding in sensory neurons*, The Czech Science Foundation (GACR), principal investigator
2011–2012 *Neural Coding*, Office of Naval Research Global, support for the Neural Coding 2012 workshop, principal investigator
2011–2013 *The role of noise in neuronal information processing*, The Czech Science Foundation (GACR), team member
2007–2009 *Signal processing in olfactory flux detector*, Grant Agency of the Academy of Sciences of the Czech Republic, principal investigator
2005 *Marie-Curie fellowship at INRA*, Versailles, France: project No. HPMT-CT-2001-00244: "Chemical Communication in Insects"

[3] Expenses covered by the inviting party.

2004–2008 *Principles of information processing in neurons and their application*, Project Information Society, Academy of Sciences of the Czech Republic, team member

Pedagogical Activities[4]

- Supervisor of diploma thesis in the master programme *Mathematical Modelling in Physics and Technology*, Faculty of Mathematics and Physics, Charles University, Prague
- Supervisor in the PhD programme *Biomedical Informatics*, First Faculty of Medicine, Charles University, Prague
- Co-supervisor in the PhD programme *Probability, Statistics and Mathematical Modelling*, Faculty of Science, Masaryk University, Brno
- University of Geneva and Lemanic Neuroscience Doctoral School: member of the PhD thesis committee (external expert)
- Teaching in the post-gradual course "Progress in Neurosciences" (PhD programme Neurosciences, *Doctoral Study Programmes in Biomedicine*): a joint programme between the Charles University and the Czech Academy of Sciences
- **Theses supervised**:
  - Tomas Barta:
    MSc. (2016–2018): *"Information-theoretic properties of selected stochastic neuronal models"*
    PhD. (2019–2023): *"Neuronal coding and metabolic cost of information"*
  - Rimjhim Tomar:
    PhD. (2019–): *"Statistical models of information processing in neuronal systems"*
  - Kristyna Kovacova:
    MSc. (2020–2022): *"Coding of pheromone signal by olfactory receptor neurons in Agrotis ipsilon"*
    PhD. (2022–): *"Metabolic cost and information coding in neuronal networks"*

Professional Service

- **Editorial duties**
  - *Neural Processing Letters*: member of the Editorial Board since 2016
  - *BioSystems*: associate editor of the *Neural Coding 2016* and *Neural Coding 2018* special issues
  - *Mathematical Biosciences and Engineering*: associate editor of the *Neural Coding 2018* special issue
- **External assessor**
  - *The French National Research Agency (ANR)*: project reviewer
  - The *Agency for the Evaluation of Universities and Research Centers (ANVUR)*, Italy: peer reviewer
  - The *National Science Centre (NCN)*, Poland: project reviewer
  - *The Czech Science Foundation (GACR)*: member of the evaluation panel *P103 Cybernetics and information processing* (2017–2020)
- **Reviewer for scientific journals and proceedings**

  Biological Cybernetics; BioSystems; Brain Research; Brazilian Journal of Probability and Statistics; Entropy; Frontiers in Computational Neuroscience; IEEE Journal on Selected Areas in Communications, Mathematical Biosciences and Engineering; IEEE Transactions on Molecular, Biological, and Multi-Scale Communications; IEEE Transactions on NanoBioscience; IEEE Wireless Communications and Networking Conference; Journal of Neural Engineering; Journal of Theoretical Biology; Neural Computation; Neural Networks; Neural Processing Letters; Neurocomputing; Physical Review E; PLoS Computational Biology; PLoS ONE; Scientific Reports

[4]The *Czech Academy of Sciences* is a non-university public research institution, the pedagogical activities are not mandatory.

- **Organization of workshops and conferences, committee memberships**

- CNS 2020: *Workshop on Methods of Information Theory in Computational Neuroscience*
  (*Online*, 21–22, 2020)
  http://lizier.me/joseph/conferences/202007-CNS2020-ITW/
  member of the organizing committee

- *Neural Coding 2020*
  (Bothell (Seattle), USA, July 27–31, 2020)
  https://sites.uw.edu/nc2020/
  member of the scientific committee

- *The 28th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN 2020*
  (Bruges, Belgium, April 22–24, 2020)
  http://www.esann.org/
  member of the technical program committee

- *Latin American Workshop on Computational Neuroscience*
  (Sao Joao del-Rei, Brazil, September 18-20, 2019)
  http://www.lawcn.com.br/
  member of the program committee

- CNS 2019: *Workshop on Methods of Information Theory in Computational Neuroscience*
  (Barcelona, Spain, July 16–17, 2019)
  www.biomed.cas.cz/~kostal/uploads/CNS2019-ITW
  chair of the organizing committee

- *5th International Conference on Mathematical NeuroScience, ICNMS 2019*
  (Copenhagen, Denmark, June 23–16, 2019)
  http://icmns2018.inria.fr/
  member of the scientific committee

- *The 27th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN 2019*
  (Bruges, Belgium, April 24–26, 2019)
  http://www.esann.org/
  member of the technical program committee

- *Neural Coding 2018*
  (Torino, Italy, September 9–14, 2018)
  http://www.neuralcoding2018.unito.it/
  member of the scientific committee

- CNS 2018: *Workshop on Methods of Information Theory in Computational Neuroscience*
  (Seattle, USA, July 17–18, 2018)
  http://lizier.me/joseph/conferences/201807-CNS2018-ITW/
  member of the organizing committee

- *International Conference on Mathematical NeuroScience, ICNMS 2018*
  (Antibes, Juan les Pins, France, June 10–13, 2018)
  http://icmns2018.inria.fr/
  member of the program committee

- *The 26th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN 2018*
  (Bruges, Belgium, April 25–27, 2018)
  http://www.esann.org/
  member of the technical program committee

- CNS 2017: *Workshop on Methods of Information Theory in Computational Neuroscience*
(Antwerp, Belgium, July 19–20, 2017)
http://lizier.me/joseph/conferences/201707-CNS2017-ITW/
member of the organizing committee

- CNS 2016: *Workshop on Methods of Information Theory in Computational Neuroscience*
(Jeju, South Korea, July 6–7, 2016)
http://lizier.me/joseph/conferences/201607-CNS2016-ITW/
member of the organizing committee

- CNS 2015: *Workshop on Methods of Information Theory in Computational Neuroscience*
(Prague, July 22–23, 2015)
www.biomed.cas.cz/~kostal/uploads/CNS2015-ITW
main organizer (jointly with A. Dimitrov, M. Gastpar, T. Sharpee, S. Schultz)

- *Neural Coding 2014*
(Versailles, France, October 6–10, 2014)
member of the organising committee

- *Information beyond Shannon 2013*
(Prague, July 3–4, 2013)
www.biomed.cas.cz/~kostal/uploads/IBS2013
main organizer

- *Neural Coding 2012*
(Prague, September 2–7, 2012)
www.biomed.cas.cz/~kostal/uploads/NC2012/
main organizer (jointly with P. Lansky)

Skills

- **Technical skills**
  - Expertise: R, Linux, LaTeX, Scripting languages, Wolfram Mathematica, Vim
  - Proficiency: Python, Fortran, C++
- **Languages**
  - English (full professional proficiency)
  - German (limited working proficiency)

Outreach

- **Popularization of science and lectures for public**
  - Interviews for Czech Radio Vltava and Leonardo in 2008, 2012;
  - Media coverage of the Otto Wichterle prize reception: main news programme of Czech TV (June 13, 2012) and interview for Radio Impuls
  - Media coverage of the Neural Coding 2012 workshop (news programme on Czech TV CT24)
  - Brain Awareness Week 2018: public lecture at the main building of the Czech Academy of Sciences
  - Lecture at the public library in Nymburk (2022).
- **Educational collaboration**
  - Initiated (jointly with Dr. R. Kobayashi) the *Memorandum of Understanding* between the *Institute of Physiology of the Czech Academy of Sciences, Czech Republic*, and the *National Institute of Informatics, Japan*, in the area of research and education in the fields of artificial intelligence and computational neuroscience (signed by the directors in 2016)