

Pavel Tolmachev, PhD

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SUMMARY

Computational neuroscientist with 9+ years of quantitative research experience building models of the nervous system and the optimization methods used to fit them. First-authored a 2025 *Nature Machine Intelligence* paper establishing how single-unit nonlinearities bias RNNs toward structurally distinct circuit solutions that generalize differently to unseen stimuli. Current work reverse-engineers RNN models of motor control and cognition, combining dynamical systems theory, deep learning, and mechanistic interpretability to turn trained networks into circuit-level explanations. Author of `trainRNNbrain`, an open-source package for training and dissecting task-optimized RNNs. Presented at COSYNE 2023 and WCCI 2020; mentored undergraduate researchers at the Simons Foundation.

RESEARCH & TEACHING EXPERIENCE

Postdoctoral Research Associate, Tatiana Engel Lab

Oct 2021 – Present

PRINCETON NEUROSCIENCE INSTITUTE (FROM JAN 2023); COLD SPRING HARBOR LABORATORY

- 🔬 Demonstrated that the choice of single-unit nonlinearity changes the computational primitives a network builds with, so RNNs trained on identical tasks arrive at structurally distinct circuits rather than variants of one solution. Networks matched on in-distribution performance diverged behaviorally under previously unseen stimuli. First author, *Nature Machine Intelligence* 7, 1742–1754 (2025).
- 🔬 Proved that in ReLU networks the selection vector's support can change only through suppression of units receiving irrelevant stimuli, identifying a concrete circuit implementation of a mechanism previously described only at the population level. The resulting connectivity rule predicted targeted rank-one perturbations of trained RNNs that realigned selection vectors and selectively degraded behavior in one context while sparing the other. First author; talk at COSYNE 2023.
- 🔬 Reverse-engineered connectivity patterns of RNNs trained on various cognitive tasks, recovering concise circuit motifs behind each task.
- 🔬 Released the training and circuit-fitting code (`trainRNNbrain`) as an open-source package.

Shenoy Undergraduate Research Fellowship in Neuroscience (SURFiN) Mentor

Sep 2023 – May 2024

SIMONS FOUNDATION

- 🔬 Mentored an undergraduate fellow through a full research cycle: from problem formulation (reverse-engineering circuitry behind Go/NoGo task) to making conference abstract and presenting poster at SURFiN conference.

PhD Candidate, Electrical and Electronic Engineering Department

Feb 2017 – Sep 2021

THE UNIVERSITY OF MELBOURNE

Thesis: *Modeling the interaction between the respiratory and the swallowing central pattern generators.*

Advisors: Prof. Jonathan H. Manton and Dr. Mathias Dutschmann.

Awarded three competitive scholarships: Melbourne Research Scholarship, Melbourne School of Engineering Studentship, and Stawell Scholarship.

- 🔬 Modeled the synaptic interactions between the respiratory and swallowing half-center oscillators in the brainstem, producing testable predictions for breathing-swallowing coordination (bioRxiv, 2021; to be published in *Biological Cybernetics* in 2026).
- 🔬 Discovered a unified normative perspective of local learning rules for memorization of patterns in Hopfield neural networks. Using the new perspective, derived new learning rules which raise pattern-storage capacity over the standard Hebbian rule; published at IJCNN and presented at WCCI 2020 (recorded talk).
- 🔬 Designed a distributed transmission scheduling algorithm for wireless networks based on Ising-model (IEEE SSP, 2018).
- 🔬 Built spiking neural network model of the respiratory central pattern generator with simplified Izhikevich neurons: reproduced the three-phase breathing rhythm with much more clarity and at lower computational cost (ICONIP,

2018).

Teaching Assistant and Tutor at residential colleges

Mar 2017 – Nov 2020

THE UNIVERSITY OF MELBOURNE; JANET CLARKE HALL; NEWMAN COLLEGE

- Ran workshops for Signals and Systems (2020–2021), Probability and Random Models (2018–2019), and Signal Processing (2017–2018), teaching more than **50** master's students per semester.
- Tutored undergraduates in Real Analysis, Calculus II, Quantum and Thermal Physics, and Probability Theory across 2 consecutive years at Janet Clarke Hall and Newman College.

EDUCATION

PhD, Electrical and Electronic Engineering

Feb 2017 – Sep 2021

THE UNIVERSITY OF MELBOURNE

Deep Reinforcement Learning (RL) Nanodegree

2018

UDACITY

Implemented double dueling deep Q-networks, deep deterministic policy gradient (DDPG), self-playing DDPG, and convolutional classifiers, each solving its benchmark environment to the required score threshold.

MSc & BSc, Physics — Graduated with Honours

Sep 2010 – Jan 2016

M.V. LOMONOSOV MOSCOW STATE UNIVERSITY

Specialized in solid state physics of low temperatures and superconductivity.

SKILLS & CERTIFICATES

Python, PyTorch, JAX, NumPy, SciPy, pandas, scikit-learn, Recurrent Neural Networks (RNNs), Dynamical Systems Analysis, Reinforcement Learning, Genetic Algorithm, Mechanistic Interpretability, High-Performance Computing (SLURM, GPU clusters), $\text{\LaTeX}$, Adobe Illustrator

Fundamentals of Ion Channel Function in the Brain, Florey Institute of Neuroscience and Mental Health

2018

Studied ion channel kinetics and performed hands on patch clamping recordings from *Xenopus* oocytes.

PUBLICATIONS & TALKS

- 2026 **P. Tolmachev**, R. R. Dhingra, J. H. Manton, M. Dutschmann. *Modelling of synaptic interactions between two brainstem half-centre oscillators that coordinate breathing and swallowing*. bioRxiv preprint; accepted in Biological Cybernetics, to be published in 2026.
- 2025 **P. Tolmachev**, T. A. Engel. *Single-unit activations confer inductive biases for emergent circuit solutions to cognitive tasks*. Nature Machine Intelligence, 7, pp. 1742–1754.
- 2023 **P. Tolmachev**^{*}, C. Langdon^{*}, T. A. Engel. *Linking neural dynamics and circuits: selection vector re-orientation via node inhibition*. In preparation; preprint available upon request. Presented as a contributed talk at COSYNE 2023 (recording). ^{*} Equal contribution.
- 2020 **P. Tolmachev**, J. H. Manton. *New Insights on Learning Rules for Hopfield Networks: Memory and Objective Function Minimisation*. International Joint Conference on Neural Networks (IJCNN), pp. 1–8. Presented as a talk at WCCI 2020 (recording).
- 2018 X. Li, **P. Tolmachev**, M. Pauley, J. H. Manton. *A Distributed Transmission Scheduling Algorithm for Wireless Networks Based on the Ising Model*. IEEE Statistical Signal Processing Workshop (SSP), pp. 6–10.
- 2018 **P. Tolmachev**, R. R. Dhingra, M. Pauley, M. Dutschmann, J. H. Manton. *Modeling the Respiratory Central Pattern Generator with Resonate-and-Fire Izhikevich Neurons*. International Conference on Neural Information Processing (ICONIP), Lecture Notes in Computer Science, pp. 603–615.