

Beren Millidge

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EDUCATION

University of Edinburgh Ph.D. in Machine Learning and Computational Neuroscience, supervised by Richard Shillcock	Edinburgh 2017–2021
University of Edinburgh MSc. in Artificial Intelligence, Distinction	Edinburgh 2016–2017
University of Oxford BSc. in Psychology, Philosophy, and Linguistics, First Class Honours	Oxford 2013–2016

EXPERIENCE

Conjecture Head of Research <i>Managed a research team of 4 full time researchers and 2 interns. Technical AI alignment research, primarily interpretability on large language models.</i>	London, UK September 2022 –present
Verses Research Lab Senior Research Scientist <i>Consulted on applied AI problems involving vision, robotics, and logistics</i>	Los Angeles, CA February 2022 –September 2022
University of Oxford Postdoctoral Researcher <i>Working with Rafal Bogacz on predictive coding, understanding learning and backprop in the brain, and unifying machine learning and neuroscience.</i>	Oxford, UK April 2021 –September 2022
University of Sussex Visiting Fellow <i>Worked closely with Christopher Buckley and Anil Seth on a wide range of machine learning and computational neuroscience projects. See publications list.</i>	Brighton, UK January 2020 –Current
Oxford Centre for Theoretical Neuroscience and Artificial Intelligence Student Researcher <i>Ran simulated psychophysics experiments on deep spiking neural networks and performed statistical analyses.</i>	Oxford May –August 2015

AREAS OF EXPERTISE

- **Machine Learning** Model-Based and Model-Free Reinforcement Learning, Computer Vision, Associative Memories, Transformer architectures, Predictive Coding
- **Machine Learning Libraries** Pytorch, Tensorflow, Keras, Flux.jl
- **Bayesian Inference** Variational Inference, Graphical Models, MCMC, (numpyro, Edward, Turing.jl)
- **Statistical Analysis** ANOVA, LMER

- **Web Development** Django, Flask, Nodejs, Express.js, React, Vue.js, Shiny (R)

LANGUAGES

- **Highly Experienced** Python, Javascript, Julia
- **Proficient** C++, C, Java, Rust, HTML, CSS, R
- **Conversant** CUDA, Ruby, Haskell, Elm, Bash, PHP, Typescript, MATLAB

PUBLICATIONS

- [1] N. Alonso, **B. Millidge**, J. Krichmar, and E. Neftci, “A theoretical framework for inference learning”, *arXiv preprint arXiv:2206.00164*, 2022.
- [2] C. Heins, **B. Millidge**, D. Demekas, B. Klein, K. Friston, I. Couzin, and A. Tschantz, “Pymdp: A python library for active inference in discrete state spaces”, *arXiv preprint arXiv:2201.03904*, 2022.
- [3] **B. Millidge**, T. Salvatori, Y. Song, R. Bogacz, and T. Lukasiewicz, “Predictive coding: Towards a future of deep learning beyond backpropagation?”, *arXiv preprint arXiv:2202.09467*, 2022.
- [4] **B. Millidge**, T. Salvatori, Y. Song, T. Lukasiewicz, and R. Bogacz, “Universal hopfield networks: A general framework for single-shot associative memory models”, *arXiv preprint arXiv:2202.04557*, 2022.
- [5] **B. Millidge**, Y. Song, T. Salvatori, T. Lukasiewicz, and R. Bogacz, “A theoretical framework for inference and learning in predictive coding networks”, *arXiv preprint arXiv:2207.12316*, 2022.
- [6] **B. Millidge**, Y. Song, T. Salvatori, T. Lukasiewicz, and R. Bogacz, “Backpropagation at the infinitesimal inference limit of energy-based models: Unifying predictive coding, equilibrium propagation, and contrastive hebbian learning”, *arXiv preprint arXiv:2206.02629*, 2022.
- [7] **B. Millidge**, M. Walton, and R. Bogacz, “Reward bases: Instantaneous reward revaluation with temporal difference learning”, *bioRxiv*, 2022.
- [8] T. Salvatori, L. Pinchetti, **B. Millidge**, Y. Song, R. Bogacz, and T. Lukasiewicz, “Learning on arbitrary graph topologies via predictive coding”, *arXiv preprint arXiv:2201.13180*, 2022.
- [9] T. Salvatori, Y. Song, **B. Millidge**, Z. Xu, L. Sha, C. Emde, R. Bogacz, and T. Lukasiewicz, “Incremental predictive coding: A parallel and fully automatic learning algorithm”, *arXiv preprint arXiv:2212.00720*, 2022.
- [10] Y. Song, B. G. Millidge, T. Salvatori, T. Lukasiewicz, Z. Xu, and R. Bogacz, “Inferring neural activity before plasticity: A foundation for learning beyond backpropagation”, *bioRxiv*, 2022.
- [11] A. Tschantz, **B. Millidge**, A. K. Seth, and C. L. Buckley, “Hybrid predictive coding: Inferring, fast and slow”, *arXiv preprint arXiv:2204.02169*, 2022.
- [12] M. Aguilera, **B. Millidge**, A. Tschantz, and C. L. Buckley, “How particular is the physics of the free energy principle?”, *arXiv preprint arXiv:2105.11203*, 2021.
- [13] P. F. Kinghorn, **B. Millidge**, and C. L. Buckley, “Habitual and reflective control in hierarchical predictive coding”, *arXiv preprint arXiv:2109.00866*, 2021.
- [14] P. Lanillos, C. Meo, C. Pezzato, A. A. Meera, M. Baïoumy, W. Ohata, A. Tschantz, **B. Millidge**, M. Wisse, C. L. Buckley, *et al.*, “Active inference in robotics and artificial agents: Survey and challenges”, *arXiv preprint arXiv:2112.01871*, 2021.
- [15] **B. Millidge**, “Applications of the free energy principle to machine learning and neuroscience”, *arXiv preprint arXiv:2107.00140*, 2021.
- [16] **B. Millidge**, “Towards a mathematical theory of abstraction”, *arXiv preprint arXiv:2106.01826*, 2021.
- [17] **B. Millidge**, A. Seth, and C. L. Buckley, “Predictive coding: A theoretical and experimental review”, *arXiv preprint arXiv:2107.12979*, 2021.
- [18] **B. Millidge**, A. Tschantz, A. Seth, and C. Buckley, “Neural kalman filtering”, *arXiv preprint arXiv:2102.10021*, 2021.

- [19] **B. Millidge**, A. Tschantz, A. Seth, and C. Buckley, “Understanding the origin of information-seeking exploration in probabilistic objectives for control”, *arXiv preprint arXiv:2103.06859*, 2021.
- [20] A. D. Noel, C. van Hoof, and **B. Millidge**, “Online reinforcement learning with sparse rewards through an active inference capsule”, *arXiv preprint arXiv:2106.02390*, 2021.
- [21] **B. Millidge**, A. Tschantz, and C. L. Buckley, “Predictive coding approximates backprop along arbitrary computation graphs”, *arXiv preprint arXiv:2006.04182; Submitted to ICLR 2021*, 2020.
- [22] **B. Millidge**, A. Tschantz, and C. L. Buckley, “Whence the expected free energy?”, *Neural Computation*, 2020.
- [23] **B. Millidge**, A. Tschantz, C. L. Buckley, and A. Seth, “Activation relaxation: A local dynamical approximation to backpropagation in the brain”, *arXiv preprint arXiv:2009.05359; submitted to ICLR 2021*, 2020.
- [24] **B. Millidge**, A. Tschantz, C. L. Buckley, and A. Seth, “Investigating the scalability and biological plausibility of the activation relaxation algorithm”, *arXiv preprint arXiv:2009.05359; submitted to NeurIPS 2020 workshop, Beyond Backpropagation in the Brain*, 2020.
- [25] **B. Millidge**, A. Tschantz, A. Seth, and C. L. Buckley, “Relaxing the constraints on predictive coding models”, *arXiv preprint arXiv:2010.01047; submitted to Neural Networks*, 2020.
- [26] **B. Millidge**, A. Tschantz, A. K. Seth, and C. L. Buckley, “On the relationship between active inference and control as inference”, *IEEE IWAI Workshop on Active Inference*, 2020.
- [27] **B. Millidge**, A. Tschantz, A. K. Seth, and C. L. Buckley, “Reinforcement learning as iterative and amortised inference”, *arXiv preprint arXiv:2006.10524*, 2020.
- [28] A. Seth, **B. Millidge**, C. L. Buckley, and A. Tschantz, “Curious inferences: Reply to sun & firestone on the dark room problem”, *Trends in Cognitive Science*, 2020.
- [29] A. Tschantz, **B. Millidge**, A. K. Seth, and C. L. Buckley, “Control as hybrid inference”, *ICML 2020 Workshop on Theoretical Foundations of RL*, 2020.
- [30] A. Tschantz*, **B. Millidge***, A. K. Seth, and C. L. Buckley, “Reinforcement learning through active inference”, *ICML 2020 Workshop Bridging AI and Cognitive Science*, 2020.
- [31] **B. Millidge**, “Combining active inference and hierarchical predictive coding: A tutorial introduction and case study”, *PsyArxiv; Submitted to Cognition*, 2019.
- [32] **B. Millidge**, “Deep active inference as variational policy gradients”, *Journal of Mathematical Psychology*, vol. 96, p. 102348, 2019.
- [33] **B. Millidge**, “Fixational eye movements: Data augmentation for the brain?”, *PsyArxiv*, 2019.
- [34] **B. Millidge**, “Implementing predictive processing and active inference: Preliminary steps and results”, *PsyArxiv*, 2019.
- [35] R. Shillcock, **B. Millidge**, and A. Ravnani, “Exploring infant vocal imitation in *tadarida brasiliensis mexicana*”, in *Neurobiology of Speech and Language*, 2019, pp. 36–37.
- [36] **B. Millidge** and R. Shillcock, “A predictive processing account of bottom-up visual saliency using cross-predicting autoencoders”, *PsyArxiv*, 2018.

AWARDS

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- Best Dissertation in Artificial Intelligence Award, University of Edinburgh 2017
 - Highest Performance in Prelims Linguistics, University of Oxford 2014