Beren Millidge

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EDUCATION

University of Edinburgh — Edinburgh
Ph.D. in Machine Learning and Computational Neuroscience, supervised by Richard Shillcock — 2017–2021

University of Edinburgh — Edinburgh
MSc. in Artificial Intelligence, **Distinction** — 2016–2017

University of Oxford — Oxford
BSc. in Psychology, Philosophy, and Linguistics, **First Class Honours** — 2013–2016

EXPERIENCE

Conjecture — London, UK
Head of Research — September 2022 –present
Managed a research team of 4 full time researchers and 2 interns. Technical AI alignment research, primarily interpretability on large language models.

Verses Research Lab — Los Angeles, CA
Senior Research Scientist — February 2022 –September 2022
Consulted on applied AI problems involving vision, robotics, and logistics

University of Oxford — Oxford,UK
Postdoctoral Researcher — April 2021 –September 2022
Working with Rafal Bogacz on predictive coding, understanding learning and backprop in the brain, and unifying machine learning and neuroscience.

University of Sussex — Brighton,UK
Visiting Fellow — January 2020 –Current
Worked closely with Christopher Buckley and Anil Seth on a wide range of machine learning and computational neuroscience projects. See publications list.

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. Baioumy, 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. Ravignani, "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

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