Lay Summary of Thesis

The lay summary is a brief summary intended to facilitate knowledge transfer and enhance accessibility, therefore the language used should be non-technical and suitable for a general audience. (See the Degree Regulations and Programmes of Study, General Postgraduate Degree Programme Regulations. These regulations are available via: http://www.drps.ed.ac.uk/.)

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Degree sought:	PhD	No. of words in the main text of thesis:	90663
Title of thesis:	Applications of the Free Energy Principle to Machine Learning and Neuroscience		

Insert the lay summary text here - the space will expand as you type.

The Free Energy Principle is an influential theory in neuroscience that posits that the brain fundamentally functions by constantly performing inference about the world by minimizing an information-theoretic quantity called the variational free energy, which effectively quantifies the discrepancy between what you expect to happen, and what actually did. All of perception, action, and learning in the brain can be interpreted as minimizing this quantity.

For perception, we work with predictive coding, a well-supported theory in neuroscience, which argues that the brain primarily operates by minimizing prediction errors (the difference between what you expected would happen and what actually happened) over time. We extend existing predictive coding networks by scaling them up using modern machine learning technologies until they can handle challenging object recognition tasks, we also develop techniques to make current predictive coding networks fit within the constraints of the known neurophysiology of the brain.

Secondly, we extend the theory of active inference – the idea that the brain minimizes free energy through action – by experimenting with agents that use artificial neural networks to learn detailed 'world models' and use these to plan out good action trajectories. We show that such agents can perform comparably with the state of the art in machine learning. We also investigate the best way to trade off exploitation (doing what you already know works) and exploration (trying new things) when deciding what to do. We demonstrate mathematically that a powerful approach is to try to optimize both simultaneously – try to get as much reward as possible while seeking out the plans that give you the most information about the world. We provide a thorough mathematical characterisation of the class of objectives which quantitatively specify how you should do this.

Finally, we look at learning and how the brain could potentially implement the backpropagation of error (backprop) algorithm. Backprop is how artificial neural networks are trained, and it computes a special 'nudge' for each individual neuron to help it get the right answer. We show that predictive coding, which is biologically plausible, can converge to the same 'nudges' as backprop.

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