Mind maths: Your personal prediction machine

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The brain's crystal ball may arise from a blend of cunning statistics and a technique that minimises surprises, linked to the laws of thermodynamics

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(Image: Aaron McCoy/Getty)

From its crackling electrical storm of activity, the brain needs to predict the surrounding world in a trustworthy way, whether that be working out which words are likely to crop up next in a conversation, or calculating if a gap in the traffic is big enough to cross the road. What lies behind its crystal-ball gazing?

One answer comes from an area of mathematics known as Bayesian statistics. Named after an 18th-century mathematician, Thomas Bayes, the theory offers a way of calculating the probability of a future event based on what has gone before, while constantly updating the picture with new data. For decades neuroscientists had speculated that the brain uses this principle to guide its predictions of the future, but Karl Friston at University College London took the idea one step further.

Friston looked specifically at the way the brain minimises the errors that can arise from these Bayesian predictions; in other words, how it avoids surprises. Realising that he could borrow the mathematics of thermodynamic systems like a steam engine to describe the way the brain achieves this, Friston called his theory "the free energy principle". Since prediction is so central to almost everything the brain does, he believes the principle could offer a general law for much, if not all, of our neural activity - the brain's equivalent of $E=mc^2$ in terms of its descriptive power and elegance.

So far, Friston has successfully used his free energy principle to describe the way neurons send signals backwards and forwards in the visual cortex in response to incoming sights. He believes the theory could also explain some of our physical actions. For instance, he has simulated our eye movements as we take in familiar or novel images, suggesting the way the brain builds up a picture with each sweep of our gaze to minimise any errors in its initial perception. In another paper he turned his attention to the delicate control of our arm as we reach for an object, using the free energy principle to describe how we update the muscle movements by combining internal signals from the turning joints with visual information (*Biological Cybernetics*, vol 102, p 227).

Others are using the concept to explain some of the brain's more baffling behaviours. Dirk De Ridder at the University of Otago's Dunedin School of Medicine in New Zealand, for instance, has used the principle to explain the phantom pains and sounds people experience during sensory deprivation. He suggests they come from the neural processes at work as the brain casts about wildly to predict future events when there is little information to help guide its forecasts (*Neuroscience and Biobehavioural Reviews*, doi.org/j9q).

Friston points out that the brain's ability to update its thoughts and make predictions about the world depends on a finely tuned system. "Signals in the brain decay," he says, and if the decay is too fast, an important hypothesis may disappear by the time the brain makes its next observation and generates a new prediction." For this reason, the free energy principle relies on the brain's ability to hang in that "critical state" on the edge of chaos. "Criticality is almost mandated by the Bayesian brain," says Friston.

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