Mind maths: Your brain teeters on the edge of chaos

06 February 2013 by **Colin Barras**
Magazine issue 2903. **Subscribe and save**
For similar stories, visit the **The Human Brain** Topic Guide

How come the cascades of impulses that spread throughout the brain don't turn into out-of-control avalanches?

Read more: "Mind maths: Five laws that rule the brain"

Avalanches, forest fires and cascades of firing neurons all share certain mathematical characteristics *(Image: Eye Ubiquitous/Rex Features)*

The familiar chords of our favourite song reach the ear, and moments later a neuron fires. Because that neuron is linked into a highly connected small-world network, the signal can quickly spread far and wide, triggering a cascade of other cells to fire. Theoretically it could even snowball chaotically, potentially taking the brain offline in a seizure.

Thankfully, the chances of this happening are slight. "Perhaps 1 per cent of the population will experience a seizure at one time in their lives," says John Beggs at Indiana University Bloomington. This suggests there is a healthy balance in the brain - it must inhibit neural signals enough to prevent a chaotic flood without stopping the traffic altogether.

The sweet spot

An understanding of how the brain hits that sweet spot emerged in the 1970s, when Jack Cowan, now at the University of Chicago, realised that this balance represents a state known as the critical point or "the edge of chaos" that is well known to theoretical physicists. Cascades of firing neurons - or "neural avalanches" - are the moments when brain cells temporarily pass this critical point, before returning to the safe side, he said.

Avalanches, forest fires and earthquakes also result from systems lying at the critical point, and they all share certain mathematical characteristics. Chief among them is the so-called "power law" distribution, which means that bigger earthquakes or forest fires happen less often than smaller ones according to a strict mathematical ratio; an earthquake that is 10 times as strong as another quake is also just one-tenth as likely to happen, for instance.

How does the brain compare? In 2003 Beggs and Dietmar Plenz, both then at the National Institute of Mental Health in Bethesda, Maryland, checked whether neural activity matches Cowan's theory by using a grid-like array of electrodes hooked to a chunk of rat cortex. Sure enough, they found that an excited neuron passed its signal to just one neighbour on average, which is exactly what you would expect of a system on the edge of chaos: any more and the system would lie in permanent, full-blown disorder. Importantly, larger neural avalanches do occur, but they are much rarer. Like earthquakes and forest fires, their frequency drops with size according to the precise ratio predicted by a power law.

Since Beggs's initial work, further functional MRI scans suggest that the same kind of edge-of-chaos activity can be found at much larger scales, across the whole human brain; indeed, computer models suggest it might be a result of the small-world structure of the brain (*New Scientist*, 27 June 2009, p 34).

Balancing on the edge of chaos may seem risky, but the critical state is thought to give the brain maximum flexibility - speeding up the transmission of signals and allowing it to quickly coordinate its activity in the face of a changing situation. Some of the researchers are beginning to wonder whether certain disorders might arise when the brain veers away from this delicate balance. "There's now some evidence that people with epilepsy are not at this critical point," says Beggs. "Just as there's a healthy heart rate and a healthy blood pressure, this may be what you need for a healthy brain."

This article appeared in print under the headline "Teetering on the edge of chaos"

***Colin Barras** is a writer based near Ann Arbor in Michigan*

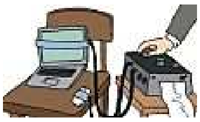
From issue 2903 of New Scientist magazine, page 36.

MORE FROM NEW SCIENTIST

Hay fever: What makes the immune system to go haywire?

Know it all: 10 secrets of successful learning

Are you deluded? The strange things we believe



Feedback: Artificial stupidity rules KO