



Human brains storage

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Human brains may store 1,000 times more information than previously thought

By **Jordan Joseph**
Earth.com staff writer

The human brain performs trillions of calculations every day while consuming about as much electricity as a dim light bulb.

Despite decades of research, scientists have never fully understood how it stores so much information or processes it with such extraordinary efficiency.

A new physics-based study offers a surprising answer.

Instead of treating neurons as independent processors, the researchers argue that groups of neurons work together as collective systems.

The team's model suggests the brain operates at nearly the theoretical limit of energy efficiency.

It also indicates that the brain can store about a thousand times more information than previous estimates and may offer a blueprint for dramatically more efficient artificial intelligence.

Seeing the brain through physics

For decades, brain science has [explained thinking through](#) single parts.

Researchers traced how one neuron fires, how a synapse passes a signal, and how brain regions communicate with one another.

That work built modern neuroscience. It never fully explained why the brain is so sparing with energy.

Wanlin Guo, a professor at Nanjing University of Aeronautics and Astronautics (NUAA), has spent his career studying the physics of materials and energy, not neurons.

Much of his best-known work focuses on nanomaterials and generating electricity from moving water. His group, with Jinxuan Ma as first author, brought that physics perspective to the brain.

The key idea was to stop looking at neurons one at a time. Instead, they treated an entire group as a single working unit and asked what it could do together.

Brains work better as teams

To study a group as a unit, the team built a simplified model neuron. Each one captured the basic shape and electrical behavior of a real cell.

They packed many of these digital neurons into a ball and let it settle into its lowest-energy arrangement. This cluster is what they call a neural sphere.

Then the researchers ran the model. They varied how the neurons were wired, how many there were, and the state in which they started.

Across these runs, the clusters did not fall silent or fire at random. Instead, they produced steady electrical rhythms that repeated over long cycles.

The team tested the idea across many nervous systems. It scaled from a roundworm with a few hundred neurons to the human brain with tens of billions.

Where a memory really lives

Those rhythms do the real work here. In this model, memories are distributed rather than localized. They reside in the pattern an entire cluster settles into after a small nudge.

Different inputs push the cluster to different starting points. From there, it settles into its own distinctive rhythm.

That rhythm both holds the information and carries it into the next step of processing.

To describe how simple groups produce such rich, stable patterns, the researchers borrowed tools from chaos theory and fractal geometry.

Both fields examine how order emerges from tangled, repeating motion.

This is the part that departs most from standard accounts. Until now, most estimates of brain capacity added up the states of individual synapses.

Treating information as a collective, moving pattern opens far more room.

Rethinking the brain's capacity

That extra room shows up in the numbers. The model predicts a memory capacity for the human brain of about 7.5 billion gigabytes.

That is roughly a thousand times greater than estimates based on counting synaptic states.

The synapse-counting approach had already produced surprises. One widely cited study mapped the fine wiring in a piece of brain tissue.

The researchers found that each synapse holds far more information than expected.

The new framework pushes the total much higher by treating storage as something dynamic rather than fixed.

The model also estimates raw processing power. It puts the brain at about 78,000 high-end graphics cards' worth of computation. All of that runs in a living person on roughly 20 watts.

Brains are almost perfectly efficient

The efficiency claim rests on a rule from physics. Erasing a single bit of information carries a minimum energy cost known as the Landauer limit.

It is the floor set by thermodynamics, and no computer can beat it.

By the model's accounting, the brain's information handling costs about 1.26 times that floor. That works out to an efficiency of nearly 79 percent.

The floor is not just theoretical. A 2012 experiment trapped a single microscopic particle and measured the heat released as one bit was erased. The value matched the predicted minimum.

Today's best AI chips sit far above that floor. The study estimates they use around a billion times more energy than the limit to move and erase information.

That gap highlights just how efficient the brain appears to have already become.

Building smarter computer chips

What is new here is a way of counting. Brain function is described not as signals in single cells but as patterns spread across cooperating groups.

That view predicts both a much larger memory and an efficiency near the physical limit.

The clearest application is in hardware. Engineers building neuromorphic chips – processors modeled on the brain – now have a concrete target and a possible strategy.

Rather than driving power-hungry clocks at high voltage, future designs could rely on the collective rhythms this model describes.

The estimates are bold, and they come from a model rather than direct recordings so that other groups will test them.

Even so, the work gives brain science and chip design a shared principle.

The brain can store information in the collective motion of many parts, and doing it that way is remarkably energy efficient.

The study is published in the journal *National Science Review*.