PRESS RELEASE

Efficient coding: how the brain optimizes allocation of resources

A collaboration between SISSA and the University of Pennsylvania indicates the existence of an efficient process of sensory coding in rats, suggesting a general principle for optimal use of computational resources. The study, published in *eLife*, paves the way for an understanding of the underlying neuronal mechanisms behind this efficiency and for the development of artificial intelligence systems based on similar principles.

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The brains of human beings at rest are supposed to use a fifth of the energy produced by their bodies, i.e., about 20 W of power. In fact, the cost would be much more if our brains were not equipped with an efficient coding mechanism that allows us to represent only the information which is really useful in the vast, ongoing stream of sensory stimuli. A new study conducted by SISSA and the University of Pennsylvania, published in *eLife*, shows the existence of similar efficient coding processes for visual stimuli in rodents. The results add support to the important efficient coding theory of sensory perception, and pave the way towards new experimental approaches for understanding underlying neuronal mechanisms and the development of new training protocols for artificial vision systems.

In the early 60s, British scientist Horace Barlow proposed the efficient coding hypothesis. “According to this theory our brain can efficiently represent sensory information using a neural code that minimizes the number of impulses, and thus the energy, necessary to encode and transmit the information,” explains Davide Zoccolan, Director of the Visual Neuroscience Laboratory at the Scuola Internazionale Superiore di Studi Avanzati – SISSA. “This happens in particular in the visual system, because of the decreasing number of neurons in the deeper areas of the cortex that reduces the representational capacity.”

According to information theory, which underpins the efficient coding hypothesis, an efficient sensory system should preferentially allocate computational resources to represent those statistical features of the environment that are more informative about its state. In the case of the visual system, this means encoding the most informative features of the natural images that surround us.

Vijay Balasubramanian, a computational neuroscientist at the University of Pennsylvania, has been working on this topic over the past decade: “We analyzed thousands of images of natural landscapes by transforming them into binary images, made up of black and white pixels, and decomposing them into different textures defined by specific statistics”, says the researcher. “We noticed that different kinds of textures have different variability in nature and human subjects are better at recognizing those which vary the most. It is as if our brains assign resources where they are most necessary.”

Until now there was no proof that similarly efficient perceptions of visual textures occur in other species. In a new study, published in *eLife*, the teams of Zoccolan and Balasubramanian have established that the effect occurs in rodents.

Riccardo Caramellino, first author of the study, together with Andrea Buccellato and Anna Carboncino, trained the animals to discriminate binary images made of random black and white pixels from textures created according to specific probabilistic criteria, as was previously done with human subjects. They then analyzed the results using a mathematical model of an ‘ideal observer’ developed by Eugenio Piasini, co-first author of the paper. The scientists observed that rodents, like humans, are most sensitive to the textures that vary the most in nature.

“We have found, in rodents, a pattern of perceptual sensitivity for visual textures that is consistent with efficient coding and is the same as the one previously observed in humans, despite the phylogenetic distance between these species. This result suggests that efficient texture coding may be a universal principle in vision,” Zoccolan comments. “The visual system seems to adapt to the surrounding environment through a sort of passive exposure, becoming specialized in the recognition of signals which are more informative, thus allowing considerable saving of computational resources and energy. Our study paves the way for new experimental approaches to investigate the neuronal mechanisms behind this fundamental process. It also suggests new ways of training artificial vision systems, based on the same principle.”

USEFUL LINK
Full paper:
elifesciences.org/articles/72081

IMAGE
“Binary landscape”
Credits: Eugenio Piasini

CONTACTS
SISSA
Chiara Saviane
→ saviane@sissa.it
T +39 040 3787230
M +39 333 7675962
Nico Pitrelli
→ pitrelli@sissa.it
T +39 040 3787462
M +39 339 1337950

University of Pennsylvania
Erica K. Brockmeier
→ ekbrock@upenn.edu
T +1 (215) 898-8562
M +1 (215) 287-8317