2025.

Our brain is a network of densely interconnected regions linked by bidirectional connections, whose nature and role in opposite directions are still far from fully understood. In their study published in *Nature Communications*, researchers from the Computational Systems Neuroscience Group of HUN-REN Wigner Research Centre for Physics described a new type of AI-based visual system model. This new AI-based model architecture not only represents a major advance in modeling brain function but could also make machine vision systems more reliable and more accurate.

To understand the neural code, we need to know how neurons interpret environmental stimuli. The brain's visual cortex relies on a hierarchy of processing units when inferring what we see and what the observed visual stimulus consists of. Within this hierarchy, neurons gradually recognize increasingly complex components. AI tools help to precisely characterize the individual steps of the multi-stage process of vision.

The most widespread tools of artificial intelligence are deep discriminative models. These are the models that can confidently recognize a French bulldog in photos on our phones. However, their operation differs from that of the nervous system: in these models, information flows in only one direction, processing visual input step by step before generating an output. In the nervous system — and specifically in the visual system — information flows in two directions. The consequence of this is dramatic: the neural code is determined not only by what has happened at earlier stages of processing, but also by what occurs at subsequent stages.

In their work, Ferenc Csikor, Balázs Meszéna, Katalin Ócsai and Gergő Orbán showed that this more complex, bidirectional information flow is linked to the fact that the nervous system solves a more sophisticated task than the image-recognition algorithms embedded in our phones. The nervous system must flexibly meet multiple challenges (Fig 1) — beyond identifying the type of animal observed, we may also need to decide whether the animal is friend or foe, or whether it is moving toward us or away from us. To adapt flexibly to such diverse demands, traditional deep discriminative models are inadequate; instead, deep generative models (also used in AI image-generation tools) are required (Fig 1Ö.

In their research, the authors demonstrated that bidirectional information flow in the brain can explain the complex functioning of the visual cortex and helped uncover the neural processes underlying phenomena such as visual illusions. This not only contributes to a more precise understanding of how the nervous system works but may also lead to better machine vision systems.

Understanding “top-down” information flow promises not only a more accurate mapping of the neural code, but also the development of more robust and goal-oriented machine vision systems. Moreover, during the training of these new types of models, vastly more unlabeled training images can be used compared to the relatively small number of labeled images available, offering hope for the creation of machine vision systems with unprecedented accuracy.

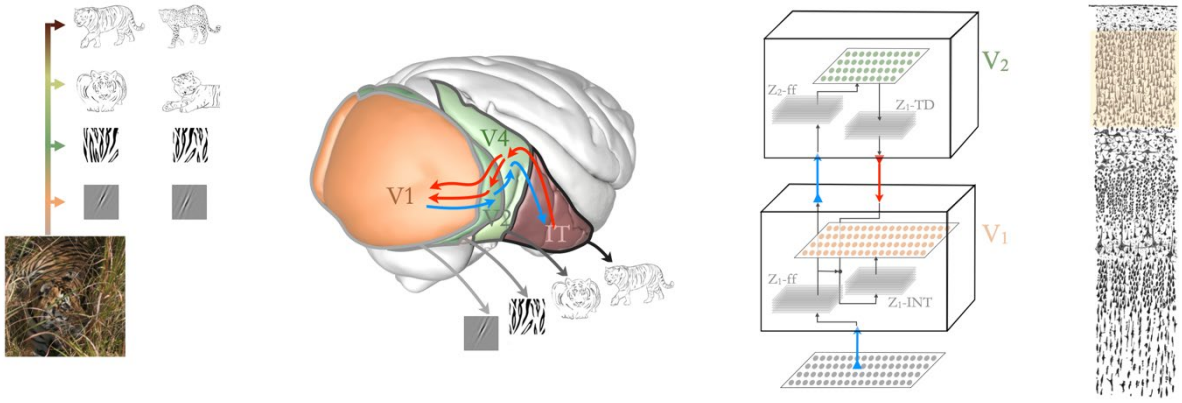

Figure 1. Deep generative model of early visual cortex.
Left: The goal of the visual cortex is to be able to flexibly perform inferences. Hierarchical inference concerns stimulus properies of different complexities that can be relevant for different tasks.

Mid-left: In the nervous system it is the hierarchy of the visual cortex that serves this computation, starting with the primary visual cortex (V1), sensitive to elementary features, and progressing through higher order cortical areas, sensitive to more complex features.

Mid—right: In a deep generative model of V1 and V2, a specific circuitry can be identified that can effectively perform hierarchical inference, and the functioning of its components can be contrasted to the responses of visual cortical neurons from the corresponding regions, thus giving an insight into the neural code. Right: the detailed architecture of the deep generative model promises to give insight into the detailed structure of the cortical circuitry.

References (choose maximum 5 articles, each must begins with https://):

[1] Csikor, F., Meszéna, B., Ócsai, K., *Orbán, G.* (2025). Top-down perceptual inference shaping the activity of early visual cortex. *Nat Commun* **16**, 9998 .