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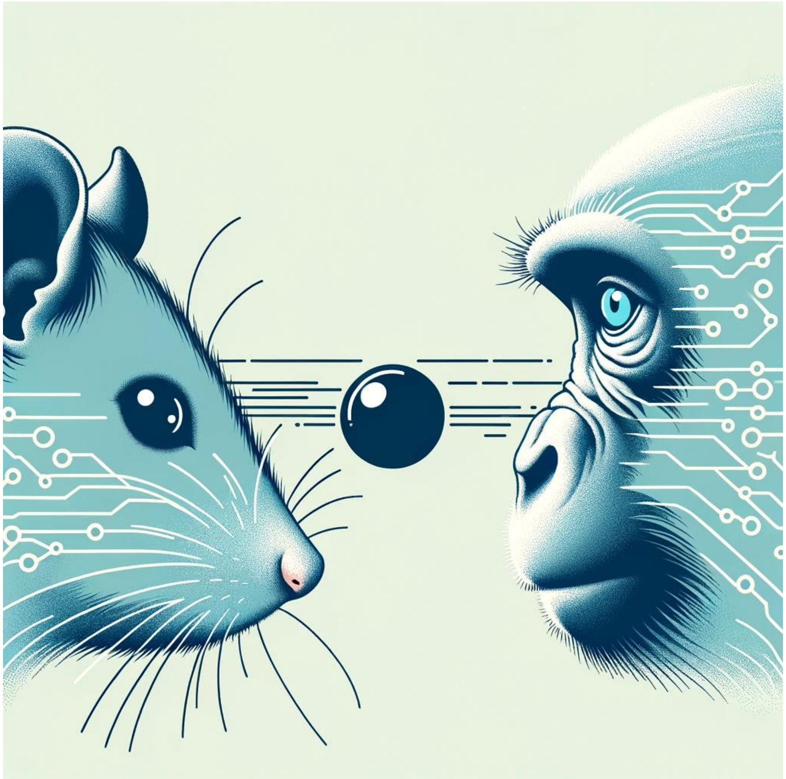
PRESS RELEASE

Similar to primates: how rodents can see moving objects

An AI-based research by SISSA has shown that rats have a small number of neurons that are able to process visual stimuli in a very sophisticated manner, enabling these animals to perceive direction correctly. The study has been published in Science Advances



Trieste, 13 November 2023

To accurately perceive the direction of moving objects, rats could exploit a small but very useful cluster of visual neurons, which seem to work in the same way as the “pattern cells” found in the cerebral cortex of primates. Thanks to these neurons, rats could rely on a rather advanced motion processing system, based on extraction of high-level visual information from retinal images.
These are the conclusions of a new SISSA study, just published in the journal Science Advances. To investigate whether the rat brain contains neurons that are

able to solve the “aperture problem”, an essential step in the accurate perception of movement, a team led by Prof. Davide Zoccolan recorded a specific group of cells in rat visual cortex and analysed their behaviour using artificial intelligence models to account for the cells’ functions. The results have shown that these neurons do have properties that are comparable to those of the “pattern cells” found in the primate visual system. Understanding the processes that underpin the functions of these cells can be useful not only to expand our understanding of the visual system but also to inspire the development of innovative artificial vision systems. This new study proves how rats are excellent animal models for this purpose, as well as for studying vision and the pathologies that can afflict it, such as neurodegenerative or neurodevelopmental disorders.

How the vision of movement works: the aperture problem

“Estimating the direction along which an object moves is a very complex computation from a perceptual point of view. Every object is made up of many different parts, which can be roughly considered as a set of oriented segments” explains Prof. Zoccolan, who led the study. Zoccolan continues: “The neurons at the initial stages of our visual system are sensitive to the presence of visual stimuli in a very small part of the visual field (their “receptive field”). This means that each of them can only “see” at any given time only one of these oriented segments. Overall, it is as if these neurons were able to break down the image of an object into many small components: lots of small, oriented segments. This decomposition is a fundamental step in the process carried out by our visual system to interpret the images collected by the retina. But it poses a challenge when it comes to perceiving movement. In fact, these neurons can only measure the motion component of an object that is perpendicular to the oriented contour they encode. To give an example: it is as if we were looking at our surroundings through a tiny hole: we would be unable to see the true, complete movement of an object. This is what the experts call the “aperture problem””.
To accurately perceive the direction of movement of a complex object, the signals provided by these neurons (known as “component” cells) need to be further processed and integrated, so as to give us a complete view of a moving object. In primates, this operation takes place along the “dorsal stream”, which starts from the primary visual cortex to reach higher-order visual areas in the parietal lobe, in an increasingly sophisticated hierarchy of functions” continues Zoccolan. The information coming from the component cells then reaches a type of specialized neurons in our visual system: the pattern cells. “These cells can process all the incoming data, then integrate them to allow us to see the movement of the object in its entirety” explains Zoccolan.

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According to Artificial Intelligence, rats also have specialised global motion detectors

“In our study, we investigated which of the cortical visual neurons in the rat were subject to the aperture problem and behaved like component cells, and which of them were immune to it and behaved like pattern cells” explains Giulio Matteucci, first author of the research. “We identified a small population of neurons of the pattern type in two different visual areas of rat cortex. This indicates that the brains of rodents also contain neurons which are able to provide a realistic view of moving objects, in a similar way as in the cortex of primates” continues the researcher. “And this, despite the obvious differences between the two species. In rodents, these types of cells are found in much smaller numbers and are scattered across various regions of the visual cortex, rather than clustered in specific areas, as it happens in primates”.
To understand whether the cells observed by the team can really be considered “pattern cells”, the researchers resorted to AI. “We worked with artificial neural networks, deep learning models which can faithfully reproduce different aspects of the behaviour of visual neurons in primates” continued Matteucci. He explains: “It was only by developing predictive models based on these neural networks that we were able to account for the responses of rat pattern cells. That was how we managed to rule out alternative hypotheses and confirm that these are in fact real pattern cells”.

Why this study is important

“Our study yielded several interesting conclusions” continued Prof. Zoccolan. “First, we found that a visual system that is much simpler than ours, and with a far shallower hierarchical structure, can nevertheless contain high-level neurons that are specialized for advanced motion processing. This is interesting from a comparative point of view. In addition, it could trigger new computational studies and inspire new models of artificial vision”. A second strength of the study concerns the prospects for future research: “Over the past 15 years, rodents have been widely used to study visual processing, both in normal and in pathological conditions. But the question, for vision scientists, remains the same: to what extent are these animals good models to investigate human visual functions? With this work, we have provided additional evidence to support the conclusion that rodent visual cortex is similar enough to ours to be worth studying it, thus leveraging the extraordinary array of experimental tools that are available in these species to examine neuronal circuits.”
In fact, future work will need to investigate in detail how these specialised neurons function in rats. Davide Zoccolan concludes: “We know that they behave

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like pattern cells, but we don't know yet the blueprint of the neuronal circuits behind this capability. This is a question that is open for future studies".

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IMAGE
Credits: Giulio Matteucci and Davide Zoccolan

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