EXPERIMENTAL ORGANISMS

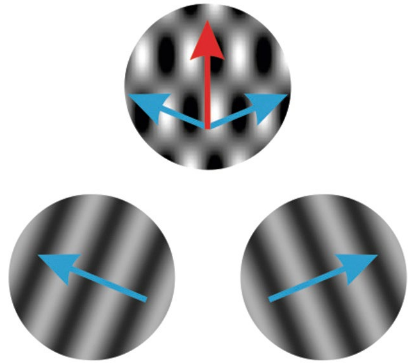
Seeing plaid: evidence of higher level motion processing found in the ferret

Lempel, A.A. and Nielsen, K.J. *Curr. Biol.* **29**, 179–191.E5 (2019)

Look at a tree blowing in the wind, or out the window into heavy rainfall. The human brain perceives that movement as an integrated whole, even though it is the individual leaves and drops of water that are actually in motion. Those are examples of higher level vision, says Kristina Nielsen, a neuroscientist at Johns Hopkins University. To understand vision, you can think about the visual system as a hierarchy, she says, in which visual information is transformed in increasingly complex ways as it moves through different parts of the brain. The retina sees the world like a camera, with information represented like pixels on a screen. That information is then transmitted via the optic nerve through the thalamus and into the primary visual cortex; there, the brain starts to interpret the edges of those pixels, processing details like orientation, spacing, and color. Those relatively raw signals are further transformed in higher-level visual areas to support more complex functions. To interpret objects in motion, signals are passed beyond the primary visual cortex into an area called the MT. At least in humans, and nonhuman primates like macaques.

Nonhuman primates are often used to study the visual system and its neurological underpinnings, but most commonly as adult animals. Rodents are used to study visual circuits too, but their brains and visual capacities are a bit different from that of a human. To understand how the visual system develops, researchers could benefit from an additional animal model that's easier to work with at earlier life stages than a nonhuman primate but that shares primates' capacity for higher level vision and motion processing. Nielsen suggests the ferret.

Ferrets are already well-established model organisms for studying vision, Nielsen says, and she has used them in her lab to help develop new neuroscience imaging methods in an animal larger than a rodent but that isn't a nonhuman primate. Anatomically, the regions of the ferret brain that make up its visual system are organized in a similar way to nonhuman primates (or at least more similarly than what is found in a rodent). That suggested to Nielsen that the ferrets might possess higher level vision to some extent, but she realized that no one had really looked that closely yet.



Schematic of the gratings and plaids patterns perceived by different neurons in different parts of the brain. Credit: Reprinted with permission from Lempel and Nielsen (2018) Elsevier.

Recently, she and her graduate student Augusto Lempel put their ferrets to the test with a classic technique established for testing higher level vision in nonhuman primates in the 1980s by Anthony Movshon at New York University. The technique involves showing the animal two grating patterns that, when superimposed in motion, produce a plaid pattern that moves in an intermediate direction. In nonhuman primates, neurons in the primary visual cortex fire in response to the individual grating but aren't sensitive to the integrated motion; it's a population of neurons found higher in brain in the MT that 'see' the plaid pattern. The former neurons are known as 'component cells' while the latter are called 'pattern cells.'

The ferrets were up to the task: electrophysiology recordings showed that individual grating were perceived by component cells in the primary visual cortex, while pattern cells fired in a region known as the PSS. Lempel and Nielsen had to make the grating just a bit wider to make up for ferret's somewhat poor visual resolution (relative to that of humans and other primates), but the same neuronal signatures of complex motion processing found in the primate MT are present in the ferret PSS. "It's a really clear transformation of something that becomes more integrated and more complex as you go from one visual area to the next," says Nielsen.

"In this elegant study, Lempel and Nielsen show the strength of the ferret as a model of the early visual system and position themselves to solve fundamental questions about the nature of cortical circuits, which have been previously unattainable," comments Benjamin Scholl, a research fellow at the Max Planck Florida Institute for Neuroscience who also works with ferrets to study visual cortical circuits. "While primates have longstanding been the standard model for understanding the visual system, it has been extremely difficult to study developmental and synaptic mechanisms underlying unique computations. Whether these computations are conserved in structure and function across mammalian species has remained an open question as well. Identifying fundamental elements of the visual across mammalian species is not only important in its own right, but allows scientists to take advantage of the attributes of different species and study different aspects of these fundamental computations."

From here, Nielsen and her lab plan to figure out the origins of the functions carried out by those different neurons in the ferret. "How does this higher area develop? And how does that fit into the development of the overall hierarchy of visual areas?" she says, questions that can be much harder to ask in a nonhuman primate, or a human for that matter. Getting awake infants or young children to stay still in an fMRI machine while looking at different visual stimuli is not entirely impossible, but it's hardly easy.

Nielsen won't be leaving nonhuman primates behind—there is still a lot to learn about vision from them, she says—but she's excited about the new addition to her model animal repertoire. With higher level vision confirmed in the ferret, she says, "we are at the starting point of being able to do an awful lot of stuff."

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Published online: 11 February 2019
https://doi.org/10.1038/s41684-019-0249-2