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A New View of Visual System Development



Image Title: Ocular dominance columns form a zebra-like pattern of stripes in part of the primary visual cortex. - Simon LeVay. *The Journal of Neuroscience*, Vol. 5, No.2, Feb. 1985

Understanding how the brain responds to and interprets visual information has occupied researchers for decades. And like the ever-changing patterns of a kaleidoscope, science's view of the visual system shifts with each new twist of insight.

Research in the laboratory of Howard Hughes Medical Institute investigator Lawrence Katz at Duke University has added a new twist that may shift that view yet again. The work deals with the question of how cells in the brain's visual cortex which processes incoming signals from the eye are organized in the brain.

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Seminal research in the 1950s and 1960s showed that specific types of nerve cells, or neurons, respond to particular shapes or orientations in the things we see. Some neurons, for example, respond to horizontal lines, some to vertical lines, some to 45-degree lines, and so on. These neurons are grouped in the visual cortex in patches called orientation columns, with those responding to a given type of stimulus occupying the same column. Other neurons are grouped into "ocular dominance columns" according to whether they process information from the left or right eye. These columns form an alternating, zebra stripe-like pattern across part of the visual cortex.

Researchers have shown conclusively that visual experience in early life is essential for the visual cortex to function properly. They also have believed, however, that long before any visual experience occurs, spontaneous neural activity helps to organize the visual cortex into its distinct pattern of patches and stripes.

Building upon these studies, investigators have developed computer models that show how spontaneous neural activity may help to wire the visual system, and in the process they have gathered data that indirectly support the idea. Still, no one had been able to record the spontaneous brain activity patterns in living animals, mainly because the task was so difficult.

In the July 23, 1999, issue of the journal *Science*, Katz and Michael Weliky, a former postdoctoral fellow in Katz's laboratory who is now an assistant professor at the University of Rochester, report results from just such experiments. "I cannot emphasize enough how difficult these experiments were to do," says Katz. "It's a real tribute to Michael, who designed and built the equipment to make it happen."

Using young ferrets whose eyes had not yet opened, the researchers recorded spontaneous activity in different layers of the lateral geniculate nucleus (LGN), an area of the brain through which information from the eyes travels on its way to the visual cortex. They found that activity in layers of the LGN associated with the two eyes was synchronized, suggesting some type of communication between the eyes.

A series of experiments showed that this communication occurs via a feedback loop between the visual cortex and the thalamus, the part of the brain in which the LGN is located. Although this loop had been known to exist, its function was unknown.

What's more, Katz and Weliky found that even when input from both eyes is cut off, the feedback loop itself can drive spontaneous activity in the LGN, suggesting that the loop plays a key role in development.

But perhaps most importantly, the two investigators found evidence that contradicts current theories on how the two eyes divide up their "territories" in the visual cortex, ending up with equal shares.

"The old theory is that inputs from the two eyes start out completely overlapping," explains Katz, "and they fight it out and separate into two independent territories with no favorites in the battle." The theory posits that this sorting-out process can occur before birth, leading researchers to conclude that spontaneous brain activity not visual input is the driving force. And for the two eyes to end up with equal-sized territories, spontaneous activity patterns for the two eyes should be equal in the LGN.

"But what we find is that the pattern of spontaneous activity is not equal for the two eyes it's profoundly unequal. Input from the eye on the opposite side of the head the so-called contralateral input is responsible for driving the entire system," says Katz. "My interpretation of this is that current theories are wrong."

He speculates that axon guidance proteins like the netrins, semaphorins and ephrins may guide the formation of ocular dominance columns. Unpublished results from subsequent experiments further support the idea, he says.

It may be some time before the whole picture comes into focus, but Katz hopes the *Science* paper will serve as an "opening salvo" that will make other vision researchers step back and view the problem from a different perspective.