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How the brain sees the world in 3-D

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Researcher Nonie Finlayson about to enter the fMRI scanner. Credit: Ohio State University

We live in a three-dimensional world, but everything we see is first recorded on our retinas in only two dimensions.

So how does the brain represent 3-D information? In a new study, researchers for the first time have shown how different parts of the brain represent an object's location in depth compared to its 2-D location.

Researchers at The Ohio State University had volunteers view simple images with 3-D glasses while they were in a functional magnetic resonance imaging (fMRI) scanner. The fMRI showed what was happening in the participants' brains while they looked at the three-dimensional images.

The results showed that as an image first enters our visual cortex, the brain mostly codes the two dimensional location. But as the processing continues, the emphasis shifts to decoding the depth information as well.

"As we move to later and later visual areas, the representations care more and more about depth in addition to 2-D location. It's as if the representations are being gradually inflated from flat to 3-D," said Julie Golomb, senior author of the study and assistant professor of psychology at Ohio State.

"The results are surprising because a lot of people assumed we might find depth information in early visual areas. What we found is that even though there might be individual neurons that have some depth information, they don't seem to be organized into any map or pattern for 3-D space perception."

Golomb said many scientists have investigated where and how the brain decodes two-dimensional information. Others had looked at how the brain perceives depth. Researchers have found that depth information must be inferred in our brain by comparing the slightly different views from the two eyes (what is called binocular disparity) or from other visual cues.

But this is the first study to directly compare both 2-D and depth information at one time to see how 3-D representations (2-D plus depth) emerge and interact in the brain, she said.

The study was led by Nonie Finlayson, a former postdoctoral researcher at Ohio State, who is now at University College London. Golomb and Xiaoli Zhang, a graduate student at Ohio State, are the other co-authors. The study was published recently in the journal *NeuroImage*.

Participants in the study viewed a screen in the fMRI while wearing 3-D glasses. They were told to focus on a dot in the middle of the screen. While they were watching the dot, objects would appear in different peripheral locations: to the left, right, top, or bottom of the dot (horizontal and vertical dimensions). Each object would also appear to be at a different depth relative to the dot: behind or in front (visible to participants wearing the 3-D glasses).

The fMRI data allowed the researchers to see what was happening in the brains of the participants when the various objects appeared on the screen. In this way, the scientists could compare how activity patterns in the visual cortex differed when participants saw objects in different locations.

"The pattern of activity we saw in the early visual cortex allowed us to tell if someone was seeing an object that was to the left, right, above or below the fixation dot," Golomb said. "But we couldn't tell from the early visual cortex if they were seeing something in front of or behind the dot.

"In the later areas of visual cortex, there was a bit less information about the objects' two dimensional locations. But the tradeoff was that we could also decode what position they were perceiving in depth."

Golomb said future studies will look to more closely quantify and model the nature of three-dimensional visual representations in the brain.

"This is an important step in understanding how we perceive our rich three-dimensional environment," she said.

Provided by The Ohio State University

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