How brain fills gaps

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A vase from China&acutes Song dynasty demonstrates the use of very faint contrast borders to create the illusion of shading on a one-color background. The phenomenon is known as edge induction. The image of the vase is overlaid over the Cornsweet illusion, in which the left half of a rectangle divided in two looks lighter and the right area darker. Holding one&acutes hand over the center of the image reveals that the left and the right are in fact the same color. The brain "fills in" the color on the left and the right in response to information from the middle border. Courtesy of Anna Roe

When in doubt about what we see, our brains fill in the gaps for us by first drawing the borders and then "coloring" in the surface area, new research has found. The research is the first to pinpoint the areas in the brain, and the timing of their activity, that are responsible for how we see borders and surfaces.

The research was published online by *Nature Neuroscience* on Aug. 19.

"When you look at objects, they can be defined as either the contour of the object or surface features, like color and brightness. There's been a debate in neuroscience about how this occurs: Do you first see the contour and then fill it in like a coloring book, or do you see the surface and from there grow it out to build the contour?" says Anna Roe, Vanderbilt University associate professor of psychology and one of the study's authors. "Our examination of individual neurons in the visual cortex revealed that the former is true — our brains process the border information first and fill in the surface information second, causing us to perceive something that is in fact not really there."

The authors open the paper with the example of vases from China's Song dynasty on which faintly contrasting carved lines create the illusion of shading on a one-color background. The phenomenon is known as edge induction, and it is believed to help us distinguish objects in dim light or through fog, or when we see objects through dappled light, such as would be found in a forest. In these conditions, the authors hypothesized that our brain seizes upon the edge and then fills in the rest of the object. In the case of the vase, we see the contrasting border and perceive that the areas within the border also are of that contrasting color, even though in fact they are the same color as the rest of the background.

The authors set out to understand what is happening at the neural level in these situations by examining activity in individual neurons in the visual cortex of cats while the cats were looking at an illusion much like the one presented by the vase. The illusion, called the Craik-O'Brien-Cornsweet illusion, is a rectangular field of gray divided in half by a shaded middle border. The area to the left of the border appears brighter than that to the right. In reality, the brighter and darker areas exist only at the border; the surrounding areas to the left and the right are the exact same brightness. The illusion causes the brain to apply the brightness and darkness it sees at the border to the areas to the left and the right.

"The Cornsweet illusion is a very good example of edge induction — taking information from the edge of an object and applying it to the rest of the object," Roe said. "It demonstrates that a lot of what you perceive is actually a construction in your brain of border information plus surface information. In other words, a lot of what you see is not accurate. We were interested in understanding how the border and surface information combine to achieve what you end up seeing."

Roe and her colleagues found that when presented with the illusion, the neurons that respond to edges fired first and the neurons that respond to texture fired second. This firing delay was only seen when the subjects perceived a brightness difference within an image; when presented with an image that did not appear different in brightness, the neurons fired at the same time.

"We found that the timing of neuronal firings is not a fixed thing in the brain, it depends on what you are looking at," Roe said. "This is a great example of neuronal activity being dependent on a stimulus that is directly correlated to how we perceive objects. It is not hardwired — neural activity and relationships between neurons change depending upon the stimulus."

The authors also discovered that the neuronal response to the illusion took place by neurons residing in two separate areas of the visual cortex.

"It seems like this kind of border-to-surface delay was really prevalent in cell pairs in the two different areas of the visual cortex," Roe said. "This is the first example of interaction between two areas underlying border-surface perception. It emphasizes in a way that hasn't been emphasized before how important inter-area relations are in visual perception.

An important implication of this study is that it emphasizes the key role of neuronal interactions in the brain, rather than simply neuronal activity level, in visual perception," Roe said. "Thus, methods that are good at detecting activity levels, such as fMRI, may miss some of these basic mechanisms. So, it's important to have different tools to assess different aspects of brain response."

Roe's co-authors were Chou P. Hung, National Yang Ming University, Taipei, Taiwan, and Benjamin M. Ramsden, West Virginia University School of Medicine.

Source: Vanderbilt University