

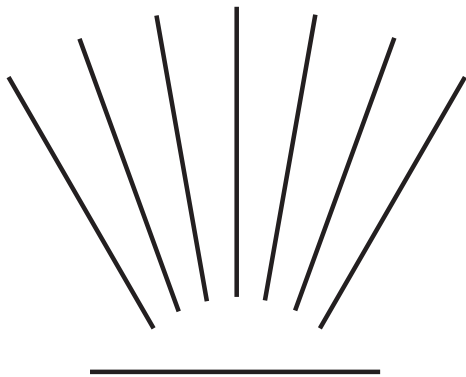
Optical Illusions: Why Do We See the Way We Do?

When Catherine Howe studies optical illusions, she's interested in more than visual tricks. Howe, an HHMI predoctoral fellow at Duke University, studies illusions to learn about the processes of brain signaling that enable our normal, everyday ability to see.

We all take vision for granted, Howe says. Like our other senses, vision usually works without calling attention to itself. Yet this very unobtrusiveness makes it difficult for scientists to understand how vision works, and some basic aspects about sight remain unexplained.

From her workstation in the lab of neurobiologist Dale Purves at Duke University Medical Center, Howe seeks to resolve what she calls “the fundamental problem of vision.” We receive visual input by way of two-dimensional retinal images that have no fixed relationship with their three-dimensional sources—any single image that falls on the retina can, in theory, be generated by an infinite number of real-world scenarios. How then do we manage to map the two-dimensional image on the retina back onto its source to somehow make our way in a three-dimensional environment?

Howe's explanation begins with an optical illusion that has intrigued scientists for more than 100 years. Given an assortment of lines of equal length, one line horizontal and



Which is longer, the single horizontal line or the lines above it? See the story for the answer.

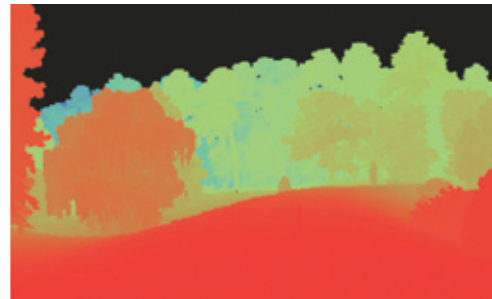
the others vertical or leaning outward like the rays of a stylized sunrise, human vision will unfailingly perceive the horizontal line as shorter than all the rest, regardless of their angle of orientation. In other words, we seem to add length mentally when we see vertical or leaning lines. This phenomenon soon becomes deeply ingrained in the way we process visual images, as anyone can demonstrate simply by drawing a square without the aid of a ruler.

“If you think you've drawn a perfect square, you haven't,” says Howe. A square that is really perfect will always appear slightly taller than it is wide, “because the brain will automatically add length to the vertical lines in the course of normal visual processing.”

What is perplexing about this and other optical illusions is the question of why the brain “misperceives” in these circumstances.

For human beings and all other seeing animals, the world contains far more variety in the size, shape, orientation and location of physical objects than any single formula for vision could address. Howe and her colleagues proposed that our interpretations of retinal images, therefore, can only be probabilistic. That is, the brain receives an image on the retina, generates a range of more or less likely interpretations and “sees” the most probable one in the light of previous visual experience. (Optical illusions, by this reasoning, occur when the most likely interpretation happens to be different from the actual circumstances giving rise to the retinal image.)

To test this hypothesis, Howe and her colleagues built a database of natural scenes, using a laser range scanner to record the three-dimensional location of each of a large sampling of points in each scene. Then, in a statistical analysis involving a massive number of calculations from the database of some 15,000



COURTESY OF PURVES LAB

Comparing a true-color image (top) with one that maps its three-dimensionality (bottom), researchers tested a hypothesis that the brain generates a range of more or less likely interpretations of an image and “sees” the one that is most probable.

images, the scientists determined the relationship between the length of a line in the retinal image and the length of the source of that line in the three-dimensional world. It turned out that, on average, the length of the physical source in three-dimensional space varies in accordance with the orientation—the angle of “leaning”—of the line in the retinal image. Basically, the real-world objects that produce standing or leaning lines in the retinal image tend to be physically longer than those that give rise to horizontal lines.

These findings confirmed their hypothesis: The reason we see vertical or “leaning” lines as being longer than horizontal ones is that in the most probable real-world scenario, the physical sources of the former are longer than the sources of the latter. Howe and Purves reported their statistical analysis last September in *Proceedings of the National Academy of Sciences*.

Howe is now at work applying her probability theory to several more optical illusions; she thinks it holds the potential to explain a great many things about the phenomenon of vision. Her mentor, Purves, concurs. “Dale likes to say that all visual perception is basically illusion,” says Howe. That thought may be disturbing, mystifying or even enlightening—depending on how you see it.

—SANDRA J. ACKERMAN