A Perspective on 3-D Visual Illusions

Paint and architectural illusions provide clues to how your brain reconstructs 3-D images

BY STEPHEN L. MACKNIK AND SUSANA MARTINEZ-CONDE

IT IS A FACT of neuroscience that everything we experience is actually a figment of our imagination. Although our sensations feel accurate and truthful, they do not necessarily reproduce the physical reality of the outside world. Of course, many experiences in daily life reflect the physical stimuli that enter the brain. But the same neural machinery that interprets actual sensory inputs is also responsible for our dreams, delusions and failings of memory. In other words, the real and the imagined share a physical source in the brain. So take a lesson from Socrates: "All I know is that I know nothing."

One of the most important tools neuroscientists use to understand how the brain creates its sense of reality is the illusion. Historically, artists as well as illusionists have used illusions to develop deep insights into the inner workings of the visual system. Long before scientists were studying the properties of neurons, artists had devised a series of techniques to "trick" the brain into thinking that a flat canvas was three-dimensional or that a series of brushstrokes was actually a still life. Applied to architecture, their work continues to astound.

Visual illusions are defined by the dissociation between physical reality and subjective perception of an object or event. When we experience such an illusion, we may see something that is not there, or fail to see something that is there, or even see something different from what is there. Because of this disconnect between perception and reality, these optical tricks demonstrate the ways in which the brain can fail to re-create the physical world. By studying these failings, we can learn about the computational methods the brain uses to construct visual experience.

Your Lying Eyes

Visual artists often try to imitate reality closely. Realistic painters convey the illusion of reality, volume or distance by making good intuitive use of perspective, color, lighting and shadow. When they are successful, the creation is sometimes difficult to distinguish from the model. Pliny the Elder, in his *Natural History,* narrates the legendary competition between two renowned painters in ancient Greece: Zeuxis and Parrhasios. Each of the artists brought a covered painting to the contest. Zeuxis uncovered his work: he had painted grapes so realistic that birds flew from the sky to peck at them. Convinced of his victory, Zeuxis tried to uncover Parrhasios's painting to confirm the superiority of his work. He was defeated, however, because the curtain he tried to pull back was Parrhasios's painting itself.

Realism in paintings did not start in ancient Greece. Even prehistoric painters used tricks to make their works appear more realistic. For instance, the Altamira bison are strategically painted over bulges of the rock, which enhances the

a

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Such realistic painting techniques were carried to the limit in **trompe l'oeil**, or illusionism.

b

c

impression of the beasts' volume (*a*).

Such techniques were carried to the limit in trompe l'oeil. Trompe l'oeil, sometimes called illusionism, is a French term that means "to trick the eye." This style of photographic realism first appeared in the Renaissance and flourished in the 17th century in the Netherlands. The lifelike pictures sometimes appeared to literally jump from the frame.

The cupola of the church of St. Ignatius of Loyola in Rome is a great example of Baroque illusionism (*b*). The architect of the church, Orazio Grassi, had originally planned to build a cupola but died before finishing the church, and the money was used for something else. Thirty years later, in 1685, Jesuit artist Andrea Pozzo was asked to paint a fake dome on the ceiling over the altar. Pozzo was already considered a master in the art of perspective, but the results he accomplished still could hardly be believed. Even today many visitors to St. Ignatius are amazed to find out that the magnificent cupola is not real, but an illusion.

Another spectacular trompe l'oeil illusion is at the Palazzo Spada, a palace in Rome that we visited last summer (*c*). Francesco Borromini created the illusion of a gallery 37 meters long in the courtyard with a life-size sculpture in daylight at the end of the archway. The gallery is actually only eight meters long, and the sculpture is just 60 centimeters tall. Even today artist Julian Beever creates perspective illusions in his sidewalk art.

A Matter of Perspective

The Leaning Tower of Pisa is not famous for its painted trickery, but it offers another architectural example that elucidates the brain's processing. In the Leaning Tower Illusion, discovered by Frederick Kingdom, Ali Yoonessi and Elena Gheorghiu of McGill University, two identical side-by-side images of the same tilted and receding object appear to be leaning at two different angles (*d*).

The Leaning Tower Illusion—which won first prize in the Neural Correlate Society's Best Visual Illusion of the Year Contest in 2007—reveals the way in which the visual system uses perspective to help reconstruct 3-D objects. We say "reconstruct" because the visual system has no direct access to 3-D information about the world. Our perception of depth results from neural calculations based on several rules. Such rules include perspective (parallel lines appear to converge in the distance), stereopsis (our left and right eyes receive horizontally displaced images of the same object, resulting in the perception of depth), occlusion (objects near us occlude objects farther away), shading, chiaroscuro (the contrast of an object as a function of the position of the light source) and sfumato (the feeling

SCALA/ART RESOURCE, NY (*cupola*); ANDREA JEMOLO *Corbis* (*gallery*)

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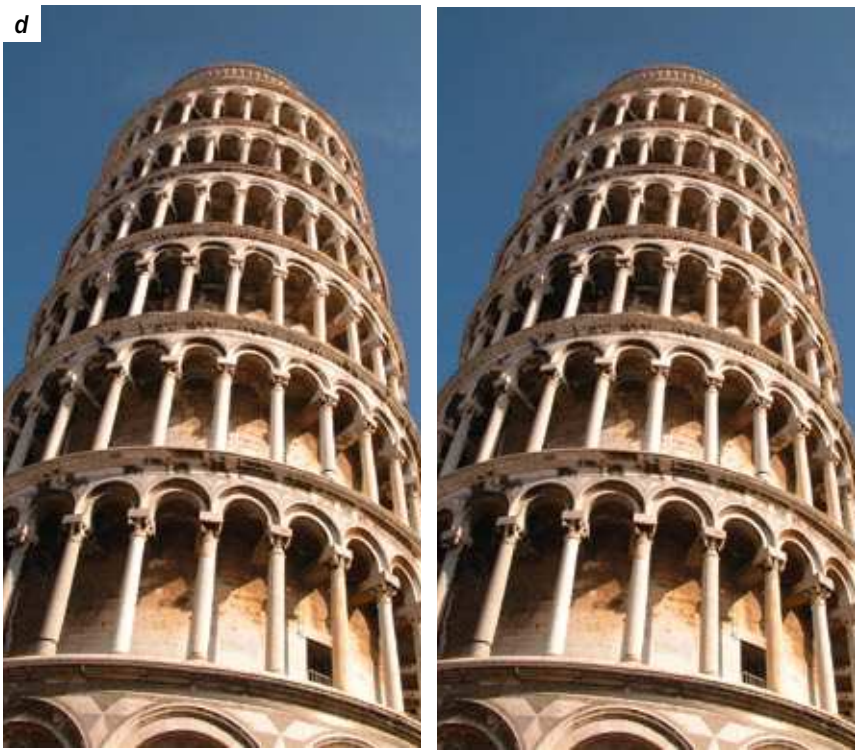

ADRIANA OLMOS; SOURCE: "THE LEANING TOWER ILLUSION: A NEW ILLUSION OF PERSPECTIVE," BY F.A.A. KINGDOM, A. YOONESSI AND E. GHEORGHIU, IN *PERCEPTION*, VOL. 36, 2007 (*Leaning Tower Illusion*); AKIYOSHI KITAOKA (*manga girls*)

of depth created by the interplay of in- and out-of-focus elements in an image as well as from the level of transparency of the atmosphere itself). The Leaning Tower Illusion shows that the brain also uses the convergence angle of two reclining objects as they recede into the distance to calculate the relative angle between them.

The illusion does not occur when we view two leaning Japanese manga girls (*e*), even though the two cartoon images are tilted. The reason is that the cartoon girls do not appear to recede in depth, so our brain does not expect that they would converge into the distance. This phenomenon demonstrates that the brain applies its depth perception tool kit only in specific situations.

3-D from 2-D

Just as the painter creates the illusion of depth on a flat canvas, our

(Further Reading)

- **Consciousness: Neurophysiology of Visual Awareness.** Stephen L. Macknik and Susana Martinez-Conde in *New Encyclopaedia of Neuroscience.* Edited by Larry R. Squire. Elsevier (in press).

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brain creates the illusion of depth based on information arriving from our essentially 2-D retinas. Visual illusions show us that color, brightness and shape are not absolute terms but are subjective, relative experiences actively created by complicated brain circuits. This is true not only of visual experiences but of any sensation. Whether we experience the feeling of "redness," the appearance of "squareness," or emotions such as love and hate, these are the results of the electrical activity of neurons in our brain.

In the movie *The Matrix*, Morpheus asks Neo: "What is real? How do you define real? If you're talking about what you can feel, what you can smell, what you can taste and see, then real is simply electrical signals interpreted by your brain." What the movie doesn't tell us is that even when Neo awakens from the fake world of the "Matrix" into the "real world," his brain will continue to construct his subjective experience, as all of our brains do, and this experience may or may not match reality. So in a way, we all live in the illusory "matrix" created by our brain. Years before *The Matrix*, neurologist and Nobel laureate Sir John Eccles wrote: "I want you to realize that there exists no color in the natural world, and no sound—nothing of this kind; no textures, no patterns, no beauty, no scent."

Or in the words of Spanish playwright Pedro Calderón de la Barca:

"What is life? A frenzy.
What is life? An illusion,
A shadow, a fiction,
And the greatest profit is small;
For all of life is a dream,
And dreams are nothing
but dreams." M

STEPHEN L. MACKNIK is director of the Laboratory of Behavioral Science, and SUSANA MARTINEZ-CONDE is director of the Laboratory of Visual Neuroscience, both of which are at the Barrow Neurological Institute in Phoenix. They thank the Mind Science Foundation (www.mindscience.org) for its generous support.

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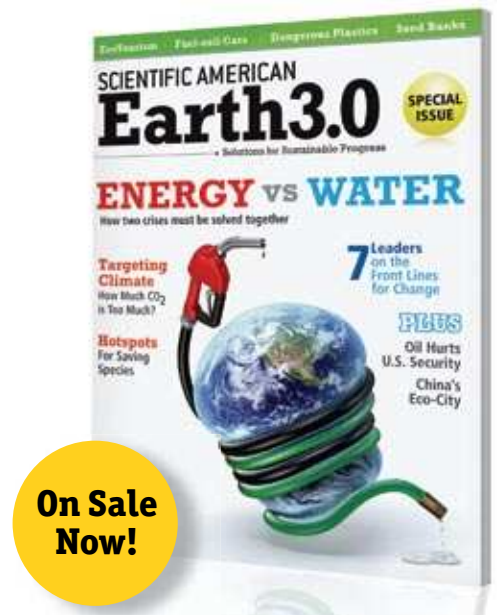

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