To what extent do we truly experience reality? By Bruce Hood

In the 1999 Hollywood blockbuster The Matrix, intelligent machines have imprisoned the human race in a state of virtual reality. They feed a computer program, the Matrix, into every brain to simulate an external real world and then harvest the imprisoned humans' biochemical electricity for their own energy needs. To the humans, their existence seems normal and mundane, but in fact, they are living an illusion.

Although the Matrix is fictional, our mind runs on its own type of virtual reality. The brain creates a model of the world that we assume is accurate most of the time. Yet in numerous instances, it is not. Visual illusions vividly illustrate the brain's mistaken interpretations. In some cases, it makes false assumptions about the world, distorting our perception.

Recent work has revealed neural activity in the brain underlying—or corresponding to—several types of illusory perceptions. Instead of simply seeing what is there, these findings suggest we are perpetually re-creating the world around us using the Matrix inside our head.

I Think, Therefore I Am

For centuries philosophers and scientists have floated the idea that the mind creates its own version of its surroundings. Plato proposed that there are dimensions to reality beyond our reach and that humans are living out only a shadow of the truth. In the 17th century René Descartes famously contemplated his own mind and came to the conclusion that experiencing reality was not foolproof and that the only certainty was the experience of thought. Hence, “I think, therefore I am.”

In the late 1800s German physician and physicist Hermann von Helmholtz recognized that illusions reveal the active processes of interpreting the external world and that these phenomena could be studied and measured. One hundred years later my former colleague Richard L. Gregory, a psychologist at the University of Bristol in England, spent much of his life investigating illusions as hypotheses that the brain generates to interpret a complicated, obfuscated and ambiguous...
world. The world does not passively impose itself on our mind; rather it has to be actively interpreted.

Some of this interpretation comes from top-down processes that reflect knowledge that is acquired through experience. For example, perspective cues in the Ames room illusion fool the brain into thinking that the room conforms to the usual geometry—all walls and floor meet at a 90-degree angle [see illustration above].

Because we assume it is a normal room, we conclude that the individuals pictured are at the same distance from the observer—and that the girl must be much larger than the two males. In reality, however, the room is a trapezoid, with the floor slanting steeply upward toward the right. The males are of equal height, and the girl is much smaller than they are. Perspective cues provide the framework for our judgments of size.

Such cues also help us to maintain constancy of perception as we move around in a world in which objects project changing size information onto the retina, the layers of light-receiving cells at the back of the eye. For example, the brain calibrates its estimate of the size of objects using other features of the environment, such as the texture of the ground. As a result, things that are farther away do not seem smaller even though they project a smaller image on the retina. A similar adjustment explains the lunar illusion in which the moon seems much larger on the horizon than it does in the sky: on the horizon, the eyes compare its size with known landmarks, whereas the sky contains no such visual guideposts.

Perspective illusions are not unique to humans. The male great bowerbird (Chlamydera nuchalis) of Australia constructs an elaborate bower made of two stick walls to create an avenue [see illustration at right]. This structure acts as a court where the female sits and watches the male perform mating displays outside. At the end where he struts his stuff, the ground is covered with a collection of shells, stones and bones.

Remarkably, the male bowerbird places objects of increasing size farther away from the vantage point of the female, creating an illusion similar to the Ames room in which the bird's stage appears foreshortened. This design is deliberate. In a study published in January, ecologists Laura Kelley and John Endler of Deakin University in Australia rearranged the objects, putting large items closer to the bower. The male bowerbirds rapidly restored the items to their original configuration. One speculation is that the illusion captures the female's attention long enough for the male to enter the bower and mate.

Other illusions are less top-down and more bottom-up—that is, rooted in the neural machinery underlying basic sensory experience. For example, when the vehicle in which you have been traveling comes to a stop, you see the world start to move in the opposite direction—an illusion called the motion aftereffect. The brain calculates direction by adding input from various movement detectors. In this effect, the visual cells that process perceived motion in the original direc-

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Cells in the brain that underlie our perception of real boundaries also respond to illusory edges such as those depicted here.

Look at the center of each of design. Which one seems brighter? Most people say the one on the left, although they are, in fact, equally bright. Nevertheless, researchers found the pupil constricts more when we look at the image on the left, indicating that our nervous systems respond to perceived brightness rather than actual luminance.

Duped Neurons

In recent years scientists have begun to investigate the bottom-up neural mechanisms that produce top-down illusions. Psychologist Gaetano Kanizsa, the late founder of the Institute of Psychology of Trieste in Italy, popularized illusory contour images, which create the impression of geometric shapes with edges and surfaces that are in fact nonexistent [see illustration at top left].

In 1984 neurophysiologist Rudiger von der Heydt and his colleagues at Johns Hopkins University discovered visual neurons called end-stopped cells that responded to real boundaries but also registered illusory contours. The activity of these cells causes the brain to interpret the illusory boundaries as real.

Since this initial discovery, a number of studies have shown that the brain treats Kanizsa shapes as if they were real objects. For example, in 1985 neurophysiologist Vilayanur S. Ramachandran of the University of California, San Diego, reported that a common trick used by animators to create the perception of an object’s movement also applies to illusory contour images. When these illusory shapes are transposed between two locations on subsequent frames, they appear to have migrated. In 2006 neuroscientists Mohamed Seghier and Patrik Vuilleumier of the University of Geneva in Switzerland published neuroimaging findings showing that the apparent movement of these shapes activates motion-sensitive regions of the visual cortex. The brain treats these geometric ghosts as if they were real moving objects.

In February psychologists Bruno Laeng and Tor Endestad of the University of Oslo in Norway used pupil dilation to reveal the most dramatic example so far of the real effects of illusions. The pupil automatically constricts in response to strong light to protect receptors in the retina from damage. Scientists have assumed that the reflex is involuntary, as it is evident in comatose patients, and that it is triggered by the amount of absolute luminance. In their study Laeng and Endestad used an infrared sensor to measure the pupil size of observers as they looked at the brightness illusion shown in the two illustrations at the top right.

Although the center of each design has the same amount of physical luminance, the pattern on the left appears subjectively brighter. Accordingly, the researchers found that participants’ pupils constricted more in response to the image on the left than to the one on the right, indicating that a subjective experience of brightness—not actual luminance—governs this response. Regardless of reality, the visual system interprets the apparently brighter pattern as a greater threat to the eye.

Researchers have also found neural correlates for illusions involving senses other than vision, such as hearing and touch. At one level, these findings are remarkable because it is generally accepted that mental experiences must have a basis in the brain. On another level, they demonstrate that we have no direct contact with reality. Our brain is always abstracting and interpreting the world around us. Even when we know the true nature of an illusion, this insight often does not change our experience. As far as the brain is concerned, if an event is an illusion, it might as well be real.

(Further Reading)

- Bright Illusions Reduce the Eye’s Pupil. Bruno Laeng and Tor Endestad in Proceedings of the National Academy of Sciences USA. Published online January 23, 2012.
- Video footage of bowerbird mating courtship and an explanation of the study by John Endler and Laura Kelley: www.youtube.com/watch?v=elwrAseBNcU