



A Moving Experience

How the eyes can see movement where it does not exist

BY VILAYANUR S. RAMACHANDRAN AND
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THE GREAT RENAISSANCE SCHOLAR and artist Leonardo da Vinci left a legacy of paintings that combined beauty and aesthetic delight with unparalleled realism. He took great pride in his work but also recognized that canvas could never convey a sense of motion or of stereoscopic depth (which requires that two eyes simultaneously view slightly different pictures). He recognized clear limits to the realism he could portray.

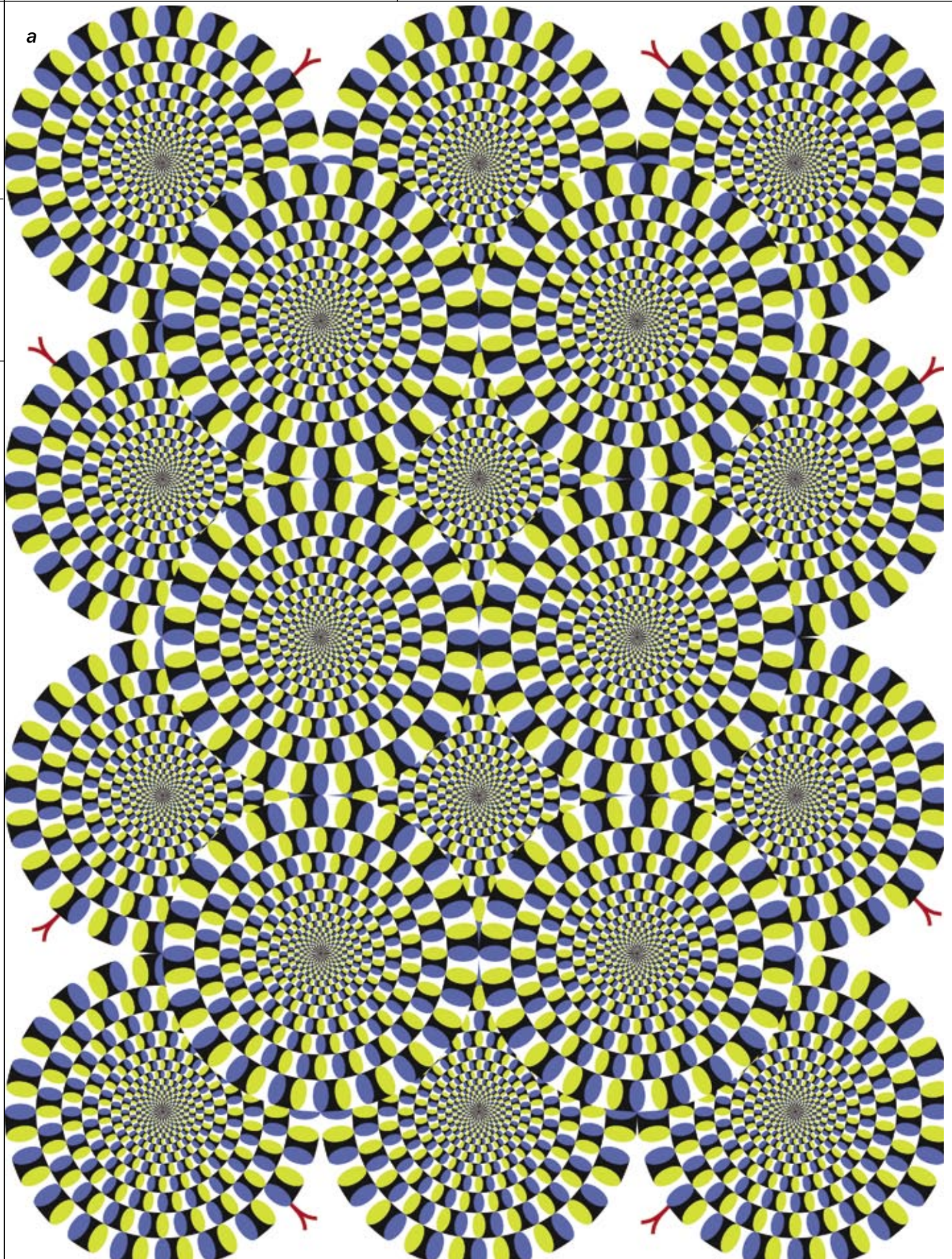
Five hundred years later the limits of depicting depth in art remain true (except of course for Magic Eye™—style prints, which, through multiple similar elements, basically interleave two views that the brain sorts out for each eye). But Leonardo could not have anticipated the Op Art movement of the 1960s, whose chief focus was to create the illusion of movement using static images. The art form grew wildly popular in the culture at large—the mother of one of us (Rogers-Ramachandran) even wallpapered an entire bathroom in a dizzying swirl of such black-and-white patterns.

The movement never really attained the status of sophisticated “high art” in the art world. Most vision scientists, on the other hand, found the images to be intriguing. How can stationary images give rise to motion?

Psychologist Akiyoshi Kitaoka of Ritsumeikan University in Kyoto, Japan, has developed a series of images called Rotating Snakes, which are particularly effective at producing illusory motion. As you gaze at *a*, you soon notice circles spinning in opposite directions. Viewing the image with your peripheral vision makes the motion

appear more pronounced. Staring fixedly at the image may diminish the sense of movement, but changing your eye position briefly by looking to one side refreshes the effect. In this image, you see movement in the direction that follows the colored segments from black to blue to white to yellow to black. Yet the colors are merely added for aesthetic appeal and have no relevance to the effect. An achromatic version (*b*, on page 54) works equally well so long as it preserves the luminance profile of the colored version (in other words, as long as the relative reflected luminance of the different patches remains the same).

These delightful displays never fail to titillate adults and youngsters alike. But why does this illusion arise? We do not know for sure. What we do know is that the odd arrangements of luminance-based edges must somehow “artificially” activate motion-detecting neurons in the visual pathways. That is, the particular patterns of luminance and contrast fool the visual system into seeing motion where none exists. (Do not be alarmed if you don’t see the movement, because some people with otherwise normal vision simply do not.)



How is a motion-detecting neuron in the brain “wired up” to detect the direction of motion?

To explore motion perception, scientists often employ test patterns of very short movies (two frames in length). Imagine in frame one a dense array of randomly placed black dots on a gray background. If, in frame two, you displace the entire array slightly to the right, you will see the patch of dots moving (jumping) to the right, because the change activates multiple motion-detecting neurons in your brain in parallel. This phenomenon is termed apparent motion, or phi. It is the basis for “motion” pictures in which no “real” motion exists, only successive still shots.

But if in the second frame you displace the dots to the right and also reverse the contrast of all the dots so that they are now white on gray (instead of black on gray), you will see motion in the opposite direction—an illusion discovered by psychologist Stuart M. Anstis, now at the University of California, San Diego. This effect is known as reversed phi, but we shall henceforth call it the Anstis-Reichardt effect, after the two vision scientists who first explored it. (The second person was Werner Reichardt, then at the Max Planck Institute for Biological Cybernetics in Tübingen, Germany.) We now know that this paradoxical reverse motion occurs because of certain peculiarities in the manner in which motion-detecting neurons, called Reichardt detectors, operate in our visual centers.

Wired for Motion

How is a motion-detecting neuron in the brain “wired up” to detect the direction of mo-

tion? Each such neuron or detector receives signals from its receptive field: a patch of retina (the light-sensing layer of tissue at the back of the eyes). When activated, a cluster of receptors in, say, the left side of the receptive field sends a signal to the motion detector, but the signal is too weak to activate the cell by itself. The adjacent cluster of retinal receptors on the right side of the receptive field also sends a signal to the same cell if stimulated—but, again, the signal is too weak on its own.

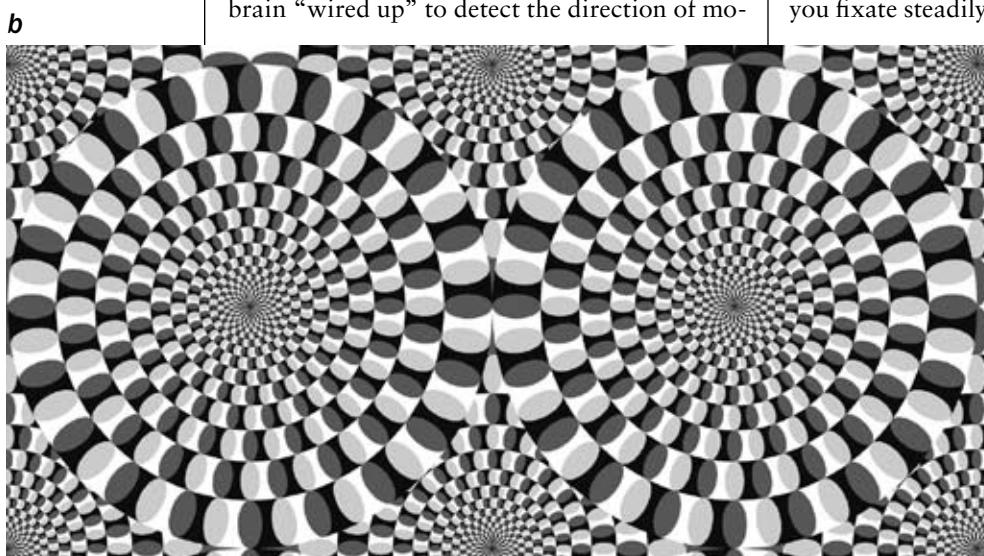
Now imagine that a “delay loop” is inserted between the first patch and the motion-detecting neuron but not between the second (right) patch and the same neuron. If the target moves rightward in the receptive field, the activity from the second patch of retina will arrive at the motion-detecting neuron at the same time as the delayed signal from the left patch. The two signals together will stimulate the neuron adequately for it to fire. Such an arrangement, akin to an AND gate, requires the circuit to include a delay loop and ensures direction as well as velocity specificity.

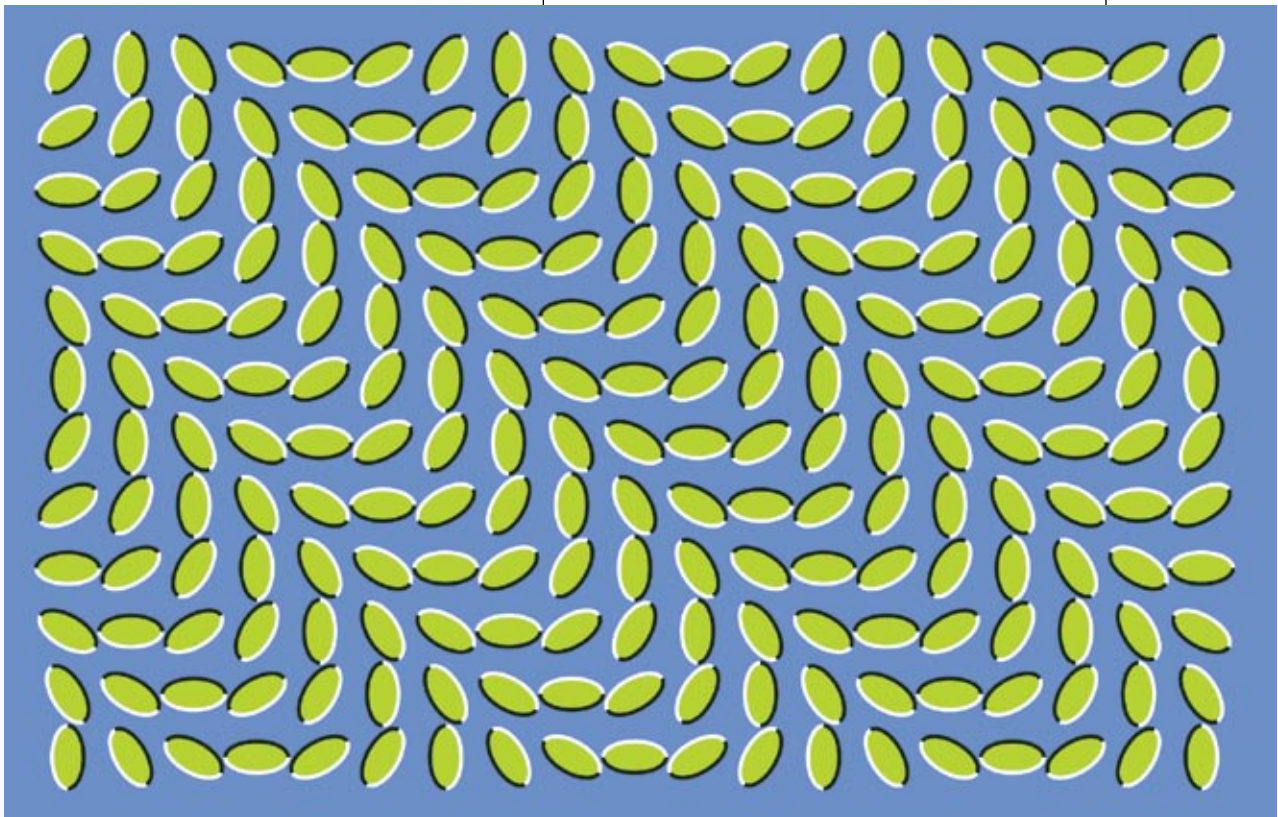
But this is only part of the story. In addition, we have to assume that for some reason we have yet to understand, stationary displays such as *a* and *b* produce differential activation within the motion receptive field, thereby resulting in spurious activation of motion neurons. The peculiar stepwise arrangement of edges—the variation in luminance and contrast—in each subregion of the image, combined with the fact that even when you fixate steadily your eyes are making ever so

tiny movements, may be critical for artificially activating motion detectors. The net result is that your brain is fooled into seeing motion in a static display.

Enhancing Motion

Finally, it is also known that patterns with a certain amount of regularity and repetitiveness will excite a large number of motion detectors in parallel, very much enhancing your subjective impression of motion. A small section of





a display such as *c* is insufficient to generate noticeable motion, although the massively parallel signals from the highly repetitive patterns together produce strong illusory motion. Readers may want to conduct a few casual experiments themselves: Is the illusion any stronger with two eyes than with one? How many almondlike shapes or snakes are necessary to see them moving?

The manner in which stationary pictures work their magic to create tantalizing impressions of motion is not fully understood. We do know, however, that these stationary displays activate motion detectors in the brain. This idea has also been tested physiologically, by recording from individual neurons in two areas of the monkey brain: the primary visual cortex (V1), which receives signals from the retina (after being relayed through the thalamus), and the middle temporal area (MT) on the side of the brain, which is specialized for seeing motion. (Damage to the MT causes motion blindness, in which moving objects look like a succession of static objects—as if lit by a strobe light.)

The question is, Would static images like the rotating snakes “fool” motion-detecting neurons? The initial answer seems to be yes, as has been shown in a series of physiological experiments published in 2005 by Bevil R. Conway of Harvard Medical School and his colleagues.

Thus, by monitoring the activity of motion-detecting neurons in animals and simultaneously exploring human motion perception using cunningly contrived displays such as *a*, *b* and *c*, scientists are starting to understand the mechanisms in your brain that are specialized for seeing motion. From an evolutionary standpoint, this capability has been a valuable survival asset as an early warning system to attract your attention—whether to detect prey, predator or mate (all of which usually move, unlike stones and trees). Once again, illusion can be the path to understanding reality. **M**

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(Further Reading)

- ◆ **Phi Movement as a Subtraction Process.** S. M. Anstis in *Vision Research*, Vol. 10, No. 12, pages 1411–1430; December 1970.
- ◆ **Perception of Illusory Movement.** A. Fraser and K. J. Wilcox in *Nature*, Vol. 281, pages 565–566; October 18, 1979.
- ◆ **Neural Basis for a Powerful Static Motion Illusion.** Bevil R. Conway, Akiyoshi Kitaoka, Arash Yazdanbakhsh, Christopher C. Pack and Margaret S. Livingstone in *Journal of Neuroscience*, Vol. 25, No. 23, pages 5651–5656; June 8, 2005.
- ◆ Stuart M. Anstis's Web site for “reversed phi” effect: <http://psy.ucsd.edu/~sanstis/SARevMotion.html>