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Illusions: Motion from Brightness

How dynamic changes in brightness cause you to see movement where there isn't any

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This is the fourth article in the Mind Matters series on the neuroscience behind visual illusions.

Benjamin Franklin once said, "Never confuse motion with action." But if motion is not action, then what exactly is motion? Let's break it down.

Imagine you are pointing your video camera at your favorite ball game. Inside your camera is a lens that focuses the image onto a CCD chip, which is a matrix of light detectors. How can a matrix of light detectors possibly see a ball rolling? The answer is, it can't. The camera doesn't see motion whatsoever, because the only thing light detectors can detect is changes in light magnitude, not light position. If the edge of the ball passes over a single light detector, the detector will react, but that's trivially due to fact that the light level on the detector changed as the ball changed position. The same detector would react identically to a stationary edge that increased its brightness without having moved. To track the change in position of an object, you need to add something, such as a brain, that can interpret the output of all the detectors in concert.

The photoreceptors of your retina are like the CCD chip in your camera: just a matrix of light detectors. They individually respond to changes in light level, whether those changes are due to actual motion or to stationary changes in brightness. Then specialized motion-detection neurons of the brain analyze the responses from populations of photoreceptors to infer motion. So although Ben Franklin may have admonished that productive activity (action) is better than unproductive activity (motion), he was also correct in the neurobiological sense: the perception of motion need not arise from a veridical action in the world. Rather, the perception of motion occurs when dedicated motion processing neurons in your brain are activated by specific patterns of light intensity changes on your retina. Because the retina cannot distinguish between the true motion of a light and the sequenced presentation of two (or more) adjacent lights, motion detectors in the brain will sometimes misinterpret certain light sequences to be motion. Vision scientists call such sequences of light "apparent motion." This illusion is the basis of animation on TV or in movies.

The following pages depict several illusions in which the perception of motion arises from dynamic changes in brightness.

Now, do not to get confused and interpret action from any of these demonstrations. The motion is all in your head.

Elemental Conditions

The outlined edges of four rectangles modulate in contrast as compared with the centers. In the top row, the centers of the rectangle are unchanging, but the top-bottom versus left-right edges modulate in counter-phase brightness, rendering the appearance of two breathing boxes. The second row proves that this effect is due to the contrast of the centers to the edges, and not to the brightness of the edges alone, because the edges are now unchanging, and only the centers of the rectangles modulate in brightness.

This illusion was first described in 1983 by Richard L. Gregory and Priscilla F. Heard, of the University of Bristol. By showing that the apparent motion is due to the shifting position of the minimal contrast between the outside of the edges versus the inside of the edges (due to either the modulation of the edges or of the center against a stable gray background), Arthur G. Shapiro and Justin P. Charles of Bucknell University won the first prize in the Best Visual Illusion of the Year contest in 2005

House of Cards
Shapiro and Charles went further with their prize-winning entry to show that combining blocks with modulating centers could render twisting effects. When the same blocks modulate without the contrasted edges, there is no motion illusion.

Lucy in the Sky
By modulating the centers on and off with different rates, Shapiro and Charles showed that different apparent rates of motion could be attributed to different elements of the figure to create undulating shape-changing effects

Perpetual Collisions
Shapiro and Emily Knight of Bucknell University placed in the Top Ten list of the 2008 Best Visual Illusion of the Year Contest with this variant that pits background- and edge-modulated rows of diamonds against each other in a perpetual collision that never connects.

Steel Magnolias
Graphic designer Michael Pickard of Sunderland University built on these findings to create a spectacular artistic vision of wind-blown flowers, without a single moving object.

Bouncing Brains
Thorsten Hansen, Kai Hamburger and Karl R. Gegenfurtner of Giessen University were also top ten finalists in the 2007 Best Visual Illusion of the Year Contest, with this entry that shows that direction, magnitude and speed of apparent motion in a grid of brains depends on all three: the color of the brains, the direction of the brightness gradient of the brains as a function of the background brightness, and the retinal position of the brains with respect to the viewer's center of gaze.

Notice that if you focus your gaze at any one the brains, it moves less than the surrounding brains, and that if you step away from the screen, the brains move more than if you peer very closely at the image on the screen. Also, the relative speed and direction of the moving brains depends on their color and the direction of the brightness gradient they create with the background,

Swimmers #7
Knight and Shapiro combined the various effects of contrast modulation, shading, shape and color to create an unmoving image of illusory but biologically plausible motion, which placed among the top ten finalists of the 2007 Best Visual Illusion of the Year Contest. Notice that without the modulating background, the effect is lost.

FURTHER READING:

Visual dissociations of Movement, Position and Stereo Depth: Some Phenomenal Phenomena. R.L. Gregory and P.F. Heard in *Quart. J. Exp. Psychol*., 35A, 217-237, 1983.

Visual Illusions Based on Single-Field Contrast Asynchronies. A.G. Shapiro, J.P. Charles and M. Shear-Heyman in *Journal of Vision*, 5(10):2, 764-782, 2005. http://journalofvision.org/5/10/2/, doi:10.1167/5.10.2.

The Neural Correlate Society's Best Visual Illusion of the Year Contest Web site: http://illusioncontest.neuralcorrelate.com.

Further Reading
Taming Vessels to Treat Cancer
New Theories May Shed Light on Dark Matter
Smart DNA: Programming the Molecule of Life for Work and Play
Reviews: *The Superorganism*

Getting Hooked on Sin
What is preemption, and what does it mean for drug lawsuits?
Are We Hardwired with a Sense of Irony?
25 Years Later: The AIDS Vaccine Search Goes On