Dark and Bright Corners of the Mind

The brain's resources are limited. By focusing on angles, curves and line endings, your visual neurons can cut corners

BY SUSANA MARTINEZ-CONDE AND STEPHEN L. MACKNIK

Amazement awaits us at every corner.
—James Broughton,
American poet and filmmaker (1913–1999)

TO PEOPLE, THE WORLD looks richly complete in all details, like a film. The information transmitted by the retina to the brain is constrained by physical limitations, however, such as the relatively small number of nerve fibers in the optic nerve. One way our visual system overcomes these limitations—thus presenting us with the perception of a fully realized world—is by disregarding redundant features in objects and scenes, thereby extracting, emphasizing and processing only the unique components that are critical to describing an object. Next time you visit the Guggenheim Museum in New York City and see a white canvas hanging on the wall, realize that what you perceive—a rectangular field of white—and what your eyes send to your brain—information about where the canvas's edges meet the wall behind the painting—are not equivalent.

As American vision scientist Fred Attneave proposed in the 1950s, just as edges inform the viewer more than uniform fields of color, "points of maximum curvature," or discontinuities in edges, such as curves, angles and corners, are less redundant and thus contain more information than the edges themselves. British neuroscientist Horace Barlow proposed in the 1960s that the brain throws out some information, but little of what is important about the visual world is lost. This idea, known as the redundancy-reducing hypothesis, may explain why neurons at the early stages of visual processing respond more intensively to the edges of objects than to interiors. Redundancy reduction applies to other visual features as well, such as the edges of edges: curves and corners. The following featured illusions result from our brain's preoccupation with any line that is deflected. **M**

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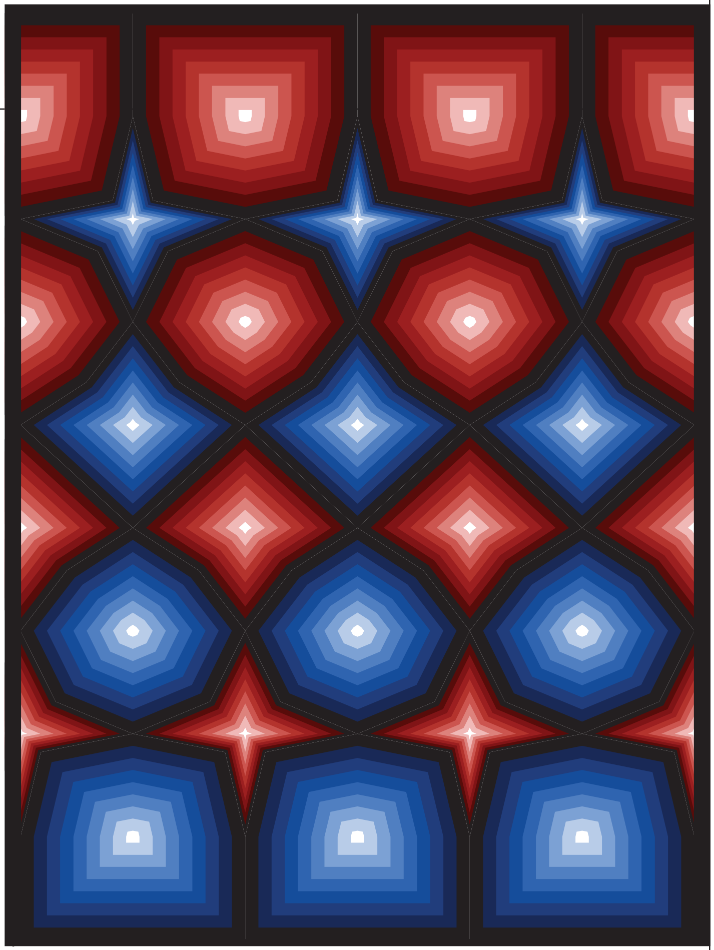


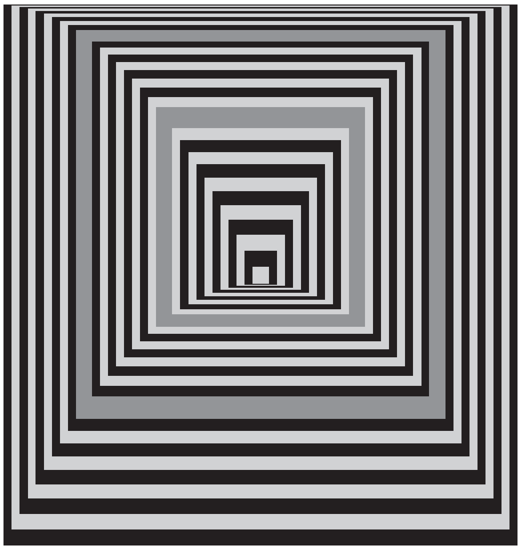
SHINING STARS

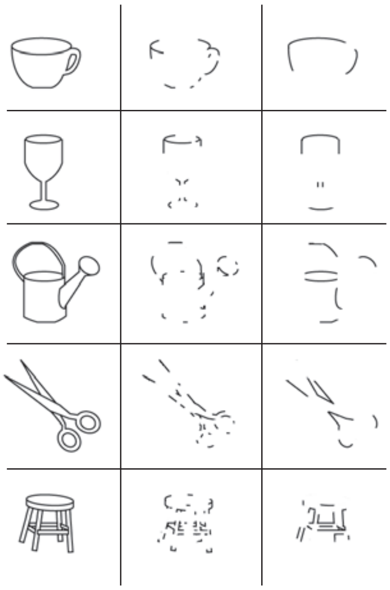
If points of high curvature are less redundant than points of low curvature, it follows that sharp corners are less redundant than shallow corners—and therefore should stand out as more salient to our visual system. The Nested Squares illusion, by Victor Vasarely, a Hungarian-French artist and founder of the op-art (short for "optical art") movement, shows illusory folds along the diagonals of concentric squares of increasing or decreasing luminance. The enhanced contrast at the corners of the squares is not physically real; it is a mind construct. The accompanying image, by neuroscientist and engineer Jorge Otero-Millan, a postdoctoral fellow in the Martinez-Conde laboratory at the Barrow Neurological Institute, shows that the strength of the illusion varies with the angle of the corner, with sharp corners generating more salient illusory folds than shallow corners. The two of us (Martinez-Conde and Macknik), along with our colleague Xoana Troncoso (at the time a Ph.D. student in the Martinez-Conde lab), first reported this effect in 2005. Notice that even though each individual polygon has the same exact physical luminance in every point, the corners seem perceptually brighter than the straight edges.

For an interactive demonstration of this illusion, visit http://smc.neuralcorrelate.com/illusions-and-demos/alternating-brightness-star

LINE THEM UP

Corner alignment in concentric polygons, as in Vasarely's Nested Squares and related illusions, affects not only apparent brightness but also depth perception. Vision neuroscientists Robert Shapley of New York University and Marianne Maertens of Technical University of Berlin studied the three-dimensional component of the illusory folds in such illusions, including those by the Native American basketry artists of the Pima (Akimel O'odham) tribe. Consistent with our findings on illusory brightness, Shapley and Maertens found that the extent of perceived depth depended on the steepness of the corner angle, with sharper corners producing stronger depth perception. In Otero-Millan's recreation of Vasarely's art (*top right*), subtle illusory folds, accompanied by the perception of depth, run across the aligned corners of the concentric squares. Some everyday objects, such as a flush fan grille (*middle right*), generate a comparable perception of 3-D. A Pima basket tray (*bottom right*) similarly induces the perception of wedges that recede or protrude in depth.



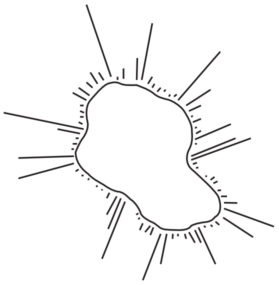


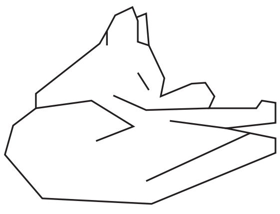
WHAT AM I LOOKING AT?

Neuroscientist Irving Biederman of the University of Southern California found that corners and curves are critical to the recognition of everyday objects. The column at the left in this grid shows line drawings of five objects. In the center column, only the high-curvature sections of their contours are visible, and object identification remains unproblematic. In the right column, only the straight edges and shallow curves appear, making the objects very difficult to recognize, although there is as much of the contour present as in the center column.

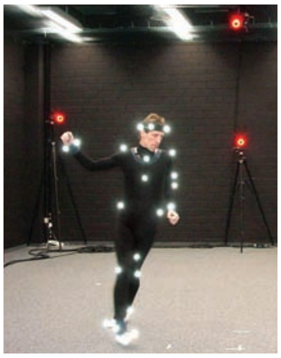
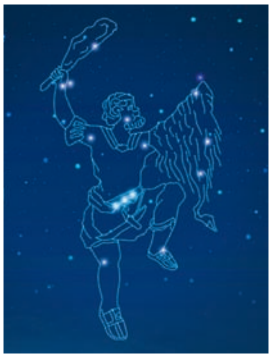
ANTIREDUNDANT

Attneave showed this blob (*near right, top*) to experiment participants and asked them to choose the 10 points that would be most useful to reconstruct its shape. The lengths of the radiating lines indicate how often subjects chose each point: participants expressed a clear preference for sharp curves and corners versus shallow curves and straight edges. The results suggested that visual neurons rely heavily on curves and other line discontinuities for processing an object's shape. To further support this idea, Attneave took the 38 points of maximum curvature from the picture of a sleeping cat. Then he played connect-the-dots, joining nearby points with straight lines, as in the children's game. The shape of the animal remained easily recognizable (*near right, bottom*).





COURTESY OF JORGE OTERO-MILLAN (*right top*); COURTESY OF BROAN-NUTONE LLC (*right middle*); COURTESY OF SMITHSONIAN NATIONAL MUSEUM OF NATURAL HISTORY (*right bottom*); SCIENTIFIC AMERICAN MIND, SOURCE: "RECOGNITION-BY-COMPONENTS: A THEORY OF HUMAN IMAGE UNDERSTANDING," BY IRVING BIEDERMAN, IN *PSYCHOLOGICAL REVIEW*, VOL. 94, NO. 2; APRIL 1987 (*What Am I Looking At?*); SCIENTIFIC AMERICAN MIND, SOURCE: "SOME INFORMATIONAL ASPECTS OF VISUAL PERCEPTION," BY FRED ATTNEAVE, IN *PSYCHOLOGICAL REVIEW*, VOL. 61, NO. 3; MAY 1954 (*Antiredundant*)

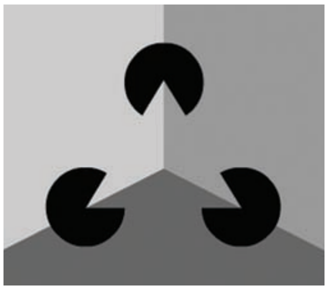
CORNERING THE FASHION MARKET

Fashion designers take advantage of the way our visual neurons are drawn to corners, curves and angles. The strategic placement of corners and bulky embellishments in these dresses by Balmain (*below left*) and Mary Katrantzou (*below right*) alters our perception of body shape, creating a slimming effect. Our visual system draws imaginary lines between the sharp corners at the shoulders, lower ribs and hips, exaggerating our perception of the models' hourglass figures.


MOVING JOINTS

Our brain's attraction to corners and angles is not limited to static objects and scenes but extends to objects in action. Pioneer Swedish psychologist Gunnar Johansson showed that observers can perceive a full body in motion from just a few shifting dots. Placing these dots on key joints, such as the wrists, elbows or knees, made the perception of biological motion stronger than when the dots were located midway between joints. In biological-motion research, scientists first record the activity of an actual walker (*above left*) and then show just the moving light dots (called point-light displays) to experiment participants. In Latin constellations, stars are similarly found at the joints of fantastic creatures and mythical heroes such as Orion (*above right*). The implied motion in the outline is reminiscent of that in stationary point-light displays.

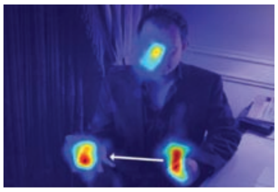
The lab Web site of Nikolaus Troje of Queen's University in Ontario features several interactive demonstrations of biological motion at www.biomotionlab.ca/?page_id=11



ILLUSORY PYRAMID

This illusion, by vision scientists Pietro Guardini and Luciano Gamberini, both then at the University of Padua in Italy, won second prize in the 2007 Best Illusion of the Year Contest. The illusory pyramid is a novel variant of the classic Kanizsa triangle, in which the phantom shape of a triangle arises from the placement of three Pac-Man shapes at an imagined triangle's corners. Guardini and Gamberini's illusion adds a background, formed by three patches with different levels of gray, to the three Pac-Men. As the angle formed by the intersection of the three gray segments varies, the illusory triangle becomes a pyramid and then reverts to the original triangle shape.

See an interactive demonstration at http://illusionoftheyear.com/2007/the-illusory-contoured-tilting-pyramid-2




CURVE OF DECEIT

Theatrical pickpocket and sleight-of-hand artist Apollo Robbins (aka "the Gentleman Thief") noticed that he could steal audiences' belongings very effectively when he used curved hand motions to draw spectators' attention away from their possessions. To find out why, some years ago we teamed up with Robbins, Otero-Millan and computational neuroscientist Michael McCamy, a postdoc in Martinez-Conde's lab, to test the effectiveness of curved versus straight hand motions in a classic trick known as the French drop.

(SPOILER ALERT: The next sentence reveals a magic secret, so move further down if you would rather not know.)

In the French drop, the magician holds a coin in one hand and pretends to take it away with the other hand to make it "disappear." In reality, the coin never leaves the original hand. We measured the eye movements of observers as they watched Robbins perform using either a curved or a straight hand motion. When he used a straight motion, people switched their gaze back and forth between the two hands. When he used a curved motion, however, they focused their gaze on the final hand only, as if they had forgotten the original location (and current hiding place) of the coin. Color overlays in the images above represent eye positions, with warm colors indicating increased ocular targeting.

(Further Reading)

- **Recognition-by-Components: A Theory of Human Image Understanding.** Irving Biederman in *Psychological Review,* Vol. 94, pages 115–147; 1987.
- **Novel Visual Illusions Related to Vasarely's "Nested Squares" Show That Corner Salience Varies with Corner Angle.** X. G. Troncoso, S. L. Macknik and S. Martinez-Conde in *Perception,* Vol. 34, No. 4, pages 409–420; 2005.
- **Angle Alignment Evokes Perceived Depth and Illusory Surfaces.** R. Shapley and M. Maertens in *Perception,* Vol. 37, No. 10, pages 1471–1487; 2008.
- **Stronger Misdirection in Curved Than in Straight Motion.** J. Otero-Millan, S. L. Macknik, A. Robbins, M. McCamy and S. Martinez-Conde in *Frontiers in Human Neuroscience,* Vol. 5, No. 133. Published online November 21, 2011.
- **The Illusionists: The Science Behind the Fall Looks That Alter Your Shape.** Esther Adams in *Vogue Daily.* Published online November 30, 2012. Available at **www.vogue.com/vogue-daily/article/the-illusionists-the-science-behind-the-fall-looks-that-flatteringly-alter-your-shape/#1**