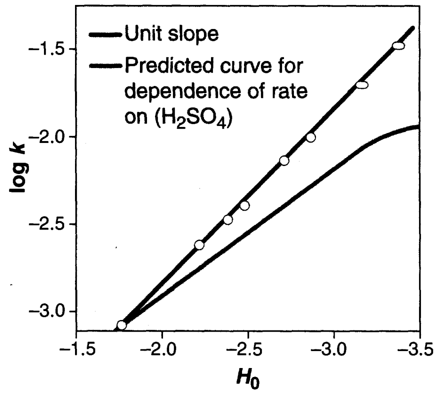
were one of the most studied fields in chemistry. Lewis Hammett published his influential book *Physical Organic Chemistry* in 1940, which popularized the use of physical techniques for the study of organic reaction mechanisms, creating legions of physical-organic chemists in the decades that followed.

One tool introduced in Hammett's book was his "acidity function," now called Hammett H_0. H_0 values, determined with overlapping indicator dyes, can measure acidities up to negative "pH" values of about −10 (which, with assumptions, is equivalent to an activity of hydrogen ions of about 10^{10} molar). I spent 3 years in the basement of the Old Chem building at the University of California at Berkeley in the 1950s, under Don Noyce, studying the kinetics and mechanisms of acid-catalyzed reactions using sulfuric in acetic acid solutions: 1 molar sulfuric acid in dry acetic acid has an H_0 of about −3 (that is, about 3 pH units more acidic than pH 0).

The figure [from (*1*)] shows a plot of



the rate constant for the acid catalyzed reaction of acetophenone with benzaldehyde to make benzalacetophenone (chalcone):

$$\text{Ph-CO-CH}_3 + \text{Ph-CHO} \xrightarrow{H^+} \text{Ph-CO-CH=CH-Ph} + H_2O$$

(Ph represents phenyl, C_6H_5.) The rate constant, *k*, is proportional to the acidity function, H_0, up to an H_0 of −3. Note that *k* does not parallel the concentration of sulfuric acid (H_2SO_4), but rather follows the H_0 function, indicating that H_0 measures acidity and not merely the molarity of added acid.

Studies using H_0 have disappeared from the literature, I now study free radical reactions in biology, Don Noyce has retired, and the only trace of the Old Chem building left on the Berkeley campus is its famous cupola, which now sits atop the Giauque Low Temperature Lab. In the 1970s, however, George Olah developed even more acidic solutions, using "superacids," and was awarded a Nobel Prize. Superacids are made from FSO_3H-SbF_5 mixtures, and extraordinary acidities (equivalent to a "pH" of around −40) are developed that are sufficient to even allow alkanes to ionize:

$$\text{R-H} + H^+ \longrightarrow R^+ + H_2$$

William A. Pryor
Biodynamics Institute, Louisiana State University, Baton Rouge, LA 70803, USA

References
1. D. S. Noyce and W. A. Pryor, *J. Am. Chem. Soc.* **77**, 1397 (1955).

Close Encounters: Details Veto Depth from Shadows

In his Perspective "Close encounters—an artist shows that size affects shape" (*Science*'s Compass, 6 Aug. 1999, p. 844), Denis G. Pelli explores a striking visual effect seen in portraits by the painter Chuck Close. The portraits are composed of many blocks or "marks" of roughly equal size, each with varying colors and details (such as ellipses or arcs) that differ from those of its neighbors. From a distance the face and its shading appear three-dimensional, but from nearby it becomes a flattened jumble of colors. Pelli notes that the depth in the face is lost when the marks are about 0.3 degree of visual angle or larger. Pelli then presents a mystery: Something prevents us from seeing the depth in the face when we are too close, and that something has to do with the marks, but it is not the marks themselves. They are still visible at the critical distance where the face and its three-dimensional depth become apparent.

We outline below a resolution to the mystery. The effect is triggered by the optics of the eye: Depth is perceived in the face when particular interfering features are not visible to the observer. However, the culprits are not the marks themselves but the small details (loops and contours) within the marks including the gaps between the details. These small details, when visible, block the perception of depth indicated by the shading in the paintings, and the nose falls flat. The marks are visible at the critical 0.3 degree size, but the smaller, offending details cannot be resolved (as we verify below). At that point, the details no longer interfere, the dark regions are seen as shadows, and the nose emerges in depth. What is most remarkable is the power of these small details to shape the interpretation of very large areas of the image.

How do the small details of Close's marks interfere with the recovery of shape from shadow? Shadows often fall on textured surfaces, so the presence of some mottled texture (the visible marks) within the shaded region does not rule out a dark area as a shadow. However, a shadow must be darker than its surround and have an appropriate border (*1*–*3*). Where a surface patch is crossed by a shadow border, the patch should change smoothly from dark to light. In 1905, Hering first showed that when a border broke this rule, the interpretation of a shadow was vetoed (*2*). He traced a dark line around a shadow so that the transition at the border went from dark to *darker* (the line), then to light. The result was that the shadow appeared to be a dark painted surface, not the light surface in shadow it actually was. Portions of Close's marks contain contours or are surrounded by light gaps (see Fig. 1). When these contours fall near the border of the shadow, they can act like Hering's lines and make it impossible for the dark regions to be taken as shadows.

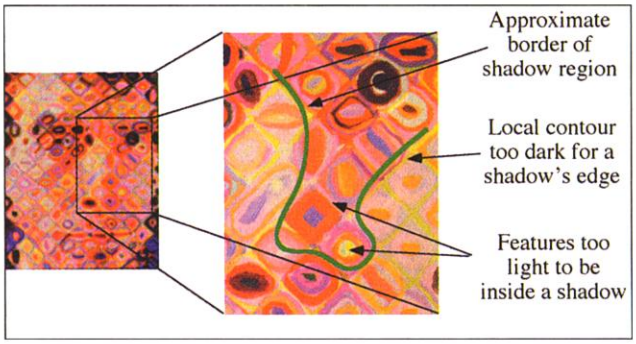


Fig. 1. Detail of *Bill II* (1991) in the nose area. Each diamond-shaped region is a "mark." The green line traces the approximate region of dark shading on the right side of the nose. Within the dark region, several of the marks have small details that are inappropriate for a shadow. For example, the dark looping contour on the right falls near the border of the shadow area and so can veto a shadow interpretation as long as it is visible. At viewing distances where the nose of *Bill II* looked flat, observers could see this particular contour. Farther away, where they saw the depth, most could not see it. (Oil on canvas, 92.4 X 76.2 cm, by Chuck Close.)

This is what Pelli has discovered in Close's paintings. Close is not the only artist to exploit the ability of small, inappropriate contours to veto depth from shadows. Giorgio Kienerk, an Italian artist at the turn of the 20th century, traced an outline around a high-contrast picture of a face (much like the example in Fig. 2A) and found, undoubtedly for the same reason as Close, that the depth of the face became hard to see.

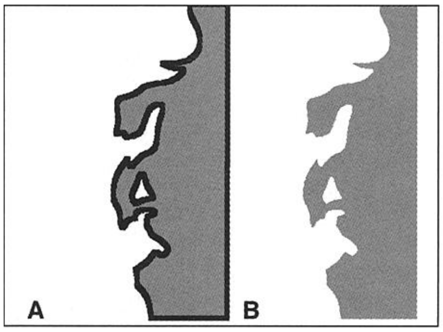


Fig. 2. Masking depth. Kennedy and Bai (*3*) darkened the contours of two-tone images like this one and found that the depth was no longer compelling. The reason the dark contour in (**A**) suppresses the depth evident in (**B**) is that a decrease in illumination that creates a shadow does not create a boundary line: The contour is inappropriate for a shadow and vetoes that interpretation and the depth it suggests. [Adapted from (*5*).]

We asked several observers to walk away from Close's painting *Bill II* until the depth in the nose became apparent. At that distance, most of them reported that they did not see any dark contour around the mark at the right edge of the nose shadow (the one bordered by a thin dark contour, see Fig. 1). They then approached the painting until the depth of the nose area was lost. At that distance all of them said they were able to see the contour. This contour is one of several inappropriate features along the shadow border. As long as these features are visible, they can veto the shadow and the depth it conveys. Moreover, the visibility of these small, interfering details is determined by standard properties of visual resolution. The power of contour artifacts to interfere with the perception of depth is the same point originally made by Harmon and Julesz (*4*) in their study of block portraits.

In summary, Pelli's interpretation is correct in identifying a critical retinal size for features that prevent the perception of depth but wrong in attributing that size to the full mark, as opposed to the smaller details within it. These small details cast the controlling vote over large expanses of apparent shadow much as a single highlight can transform an entire matte surface into a shiny one. Close has constructed his work so that the viewer can trigger this powerful visual routine at will, simply by moving closer to the painting.

Patrick Cavanagh
Department of Psychology, Harvard University, 33 Kirkland Street, USA. E-mail: patrick@wjh.harvard.edu

John M. Kennedy
Department of Psychology, University of Toronto, 1265, Military Trail, Scarborough, Ontario, Canada M1C 1A4. E-mail: kennedy@scar.utoronto.ca

References

1. P. Cavanagh and Y. Leclerc, *J. Exp. Psychol. Human Percep. Perform.* **15**, 3 (1989).
2. E. Hering, *Handbuch der gesamten Augenheilkunde* (Vol. 3, Berlin, 1905).
3. J. M. Kennedy and J. Bai, *Perception*, in press.
4. L. D. Harmon and B. Julesz, *Science* **180**, 1194 (1973).
5. C. M. Mooney, *Can. J. Psychol.* **11**, 219 (1957).

Response

Cavanagh and Kennedy elegantly apply Hering's 1905 theory to explain the disappearance of depth in Close's portraits. Their explanation that something about the marks vetoes the observer's interpretation of the dark region as a shadow is consistent with our impression that the nose of *Bill II* is invariably seen either as emergent and uniformly colored, or as flat and discolored.

However, Cavanagh and Kennedy suggest, with little evidence, that it is "small details within the marks" that prevent one from seeing the shadow and thus the emergence of the nose. The evidence they present is a correlation. They found that a particular detail is visible at distances at which the nose collapses and invisible (to "most" of their observers) at distances at which the nose emerged. First, "most" implies that at least one of their observers saw the feature when the nose emerged, contrary to their prediction. Second, the correlation does not establish causality.

Detail of *Bill II* (1991) by Chuck Close. In original form on left, and block-averaged on right. Removing details within the marks, as in the right panel, increases the viewing distance required to see the nose emerge. For the six observers, the distance increased by a factor of 1.6, 1.9, 1.8, 1.3, 2.8, and 1.9. (Oil on canvas, 92.4 x 76.2 cm.)

CREDIT: PHOTO, BILL JACOBSON. COURTESY OF PACEWILDENSTEIN

Their explanation is contradicted by a direct test. We found that by removing all detail within the marks (block-averaging within each square mark, but not across marks), the shadow and emergent nose become harder—not easier—to see. On the basis of six observers, we found that the minimum distance at which the nose emerged with the block-averaged image (as in the figure, right) was about twice as far as for the original image (figure, left). For every observer, removing the details made it harder to see the nose emerge.

Thus, we reaffirm our conclusion that the critical parameter is the size of the mark (though mark type does have some effect), but we agree with Cavanagh and Kennedy's suggestion that some aspect of large marks vetoes the shadow and collapses the nose. Perhaps the mark edges provide inappropriate contours (*1*).

Denis G. Pelli
Melanie Palomares
Psychology and Neural Science, New York University, New York, NY 10003, USA. E-mail: denis@psych.nyu.edu

References

1. V. S. Ramachandran, *Sci. Am.* **259**, 76 (August 1988).

CORRECTIONS AND CLARIFICATIONS

News Focus: "Asilomar revisited: Lessons for today? by Marcia Barinaga (3 Mar., p. 1584). The remarks of Charles Weiner quoted on p. 1585 suggested that ethical issues of recombinant DNA technology had been discussed at the 1975 Asilomar conference on recombinant DNA, which was not the case. Weiner's remarks referred to comments made by several participants interviewed shortly after the 1975 conference who said they would draw the ethical line at human germ line intervention.