This problem-solving aspect of perception is strikingly illustrated in a by the famous illusory rectangle of Italian psychologist Gaetano Kanizsa and neuropsychologist Richard L. Gregory of the University of Bristol in England. Your brain regards it as highly unlikely that some malicious scientist has deliberately aligned four Pac-men in this manner and instead interprets it parsimoniously as a white opaque rectangle partially covering four black disks in the background. Remarkably, you even fill in, or “hallucinate,” the edges of the phantom rectangle. The main goal of vision, it would seem, is to segment the scene to discover object boundaries so that you can identify and respond to them.

Now, you might think that the mere presence of collinear edges is sufficient for the brain to “complete” the gap, but b demolishes this argument. Comparing the absence of illusory contours in b with their presence in a, we conclude that the critical cue is implied occlusion.

In c, the bricks are aligned so that the edges coincide with the edges of the Pac-men. The occluding rectangle reemerges; indeed, it is actually more vivid than the illusory contour on its own. When multiple sources of information about an edge (in this case, the luminance-defined sides of the bricks and the illusory ones implied by occlusion) coincide spatially, the brain regards this coming together as compelling evidence that the edge is real.

How do we then explain the disappearance of the illusory rectangle in e—which could be logically interpreted as a textured rectangle occluding four gray disks in the background? To understand this anomaly, we need to invoke a “hardware” rather than “software” explanation. Notice that we have matched the mean luminance of the texture with that of the Pac-men. The neurons in your brain that extract the illusory edges can identify only those edges defined by luminance differences because of the way in which neurons evolved. Because the Pac-men in the display are defined by a difference of graininess, not luminance, no illusory contours are seen, even though the “logic” of the situation dictates that they should be.

In f, we superimpose an illusory circle on a simple gradient of luminance. Intriguingly, the region enclosed by the circle seems to bulge right out at you, especially if you squint your eyes to blur the image slightly. The brain deduces that the gradient must arise from a curved surface lit from above, and the illusory circle interacts with this impression to produce the final interpretation of a sphere. Yet if we superimpose a “real,” thin,
black-outline circle made of an actual luminance-based edge on the gradient, no bulge appears. This finding leads to a paradoxical aphorism that we invented to annoy philosophers—namely, that illusory contours seem more real than real contours. Such luminance edges can arise in the visual scene for any number of reasons—the edge of a shadow, for example, or the stripes of a zebra. They do not necessarily imply object boundaries.

In 1961 neurobiologists David H. Hubel and Torsten N. Wiesel, both then at Harvard University, discovered the basic alphabet of vision (they later shared a Nobel Prize in Physiology or Medicine for their efforts to understand information processing in the visual system); individual neurons in area 17 and area 18 (in the occipital lobe) fire only when lines of a certain orientation are displayed in a specific location on the screen (the “receptive field”). Many of them will respond only to a line of a specific length—if it is longer, they will stop firing (“end-stopped cells”). Neurorphysiologist Rudiger von der Heydt of Johns Hopkins University suggested that these cells are signaling an implied occlusion that is effectively chopping off the line, and sure enough, the cells respond to illusory contours.

You can demonstrate the existence of such cells in your own brain. If you stare continuously at the red dot on the right in c, you will notice that after a few seconds, the illusory rectangle fades even though you still see the bricks and Pac-men. The cells signaling the illusory edges are “fatigued” by the steady fixation, which hyper-activates them and depletes them of their chemical neurotransmitters. If you move your eyes, they reappear, because a new set of cells is recruited. Apparently these illusory contour cells are more easily fatigued than those signaling the real edges of the bricks and Pac-men.

In more complex images, cells in the earliest stages of visual processing may signal illusory edges, but top-down modulation based on visual attention can reject or accept the contours depending on overall consistency with the scene. M

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(Further Reading)