Contrast Illusions in Perspective

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The same sort of phenomenon that makes a large object seem lighter than a small object can be linked with the evolution of perspective in painting.

IN the house of the early Cubist painters in Paris lived a certain Maurice Princet, a somewhat derelict figure known to the group as Le Mathématicien. Princet is said to have addressed the following question to Picasso and Braque[1]: "You represent by means of a trapezoid a table as you see it transformed by perspective, but what would happen if the fancy struck you to express the table as a type? It would be necessary for you to place it on the plane of the canvas, and return from the trapezoid to the true rectangle."

But had he tried this formula himself, Princet, the mathematician, might have been surprised at the result. Fig. 1 shows a table, not "transformed by perspective" so that its top is a trapezoid, but rather "expressed as a type" so that its top is a perfect parallelogram. Curiously, it does not look like a parallelogram, but like a trapezoid. We are subject to a visual illusion.

The conditions responsible are easily discovered. Removing the legs from the table makes the illusion almost disappear; placing on it a vase of flowers makes it become more obvious still. The error we make in judging the shape of the parallelogram depends on our seeing it as a table-top, with the implication that it represents a receding horizontal surface. It so happens that whenever two equal lines are convincingly depicted in such a way that one appears more distant than the other, the further line looks longer than the nearer. But why should apparent depth have such an influence on perception of size?

When people make estimates of the value of sensory stimuli it is generally true that their estimate depends not only on the actual value of the stimulus but also on what they expect its value to be. Deviations from the expected value are exaggerated, so that if the value of a stimulus is less than expected it is underestimated, and if it is greater it is overestimated—the greater the discrepancy, the greater the error. Roughly, if the stimulus has an actual value of x and an expected value of E, the subjective estimate is out by an amount proportional to $x-E$.

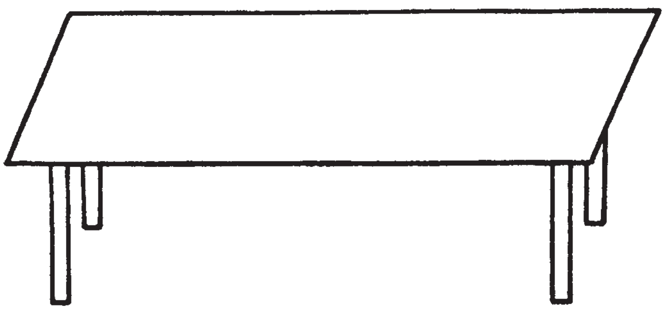

Fig. 1 For explanation see text.

In this formulation, expected value has rather a special meaning. Other things being equal, the "expectation" is conditioned simply by the prevailing sensory context, and the expected value approximates the average value of similar stimuli in the local environment. In the presence of large stimuli the expected value is high and in the presence of small stimuli it is low. Hence a particular stimulus is judged to be smaller in the former context than the latter.

These so called "contrast effects" occur in all sensory modalities. A light of a particular brightness, say a torch bulb, is judged to be dimmer in a brightly lit room than in a dark one; an interval of a particular duration, say a second, is judged to be longer in the fast movement of a symphony than in the slow one; a fruit of a particular sweetness, say an orange, is judged to be sourer when eaten with a sweet drink than with a sour one. Less familiar examples occur in the perception of visual form. Figs. 2 and 3 show the influence of contrast on the size of a circle and the orientation of a line: a circle is judged to be smaller when surrounded by large circles than by small; a line is judged to slope away from another line which crosses it.

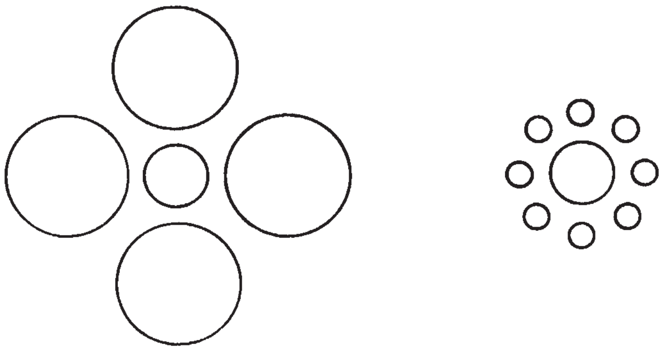

Fig. 2 A contrast illusion for size. The two central circles are equal in diameter.

The effect of a particular sensory context may persist to some extent when the context is removed, so that the subjective estimate of a particular stimulus is influenced not only by current but by previous exposure to stimuli of differing value. After wearing red glasses we see a piece of white paper to be tinged with green; after speeding along a motorway we judge a limit of 30 miles per hour to be dreadfully slow; after stepping off a heaving ship we feel the ground under our feet to be going up and down. Such after effects, too, occur for visual form. The effect for size perception can be shown

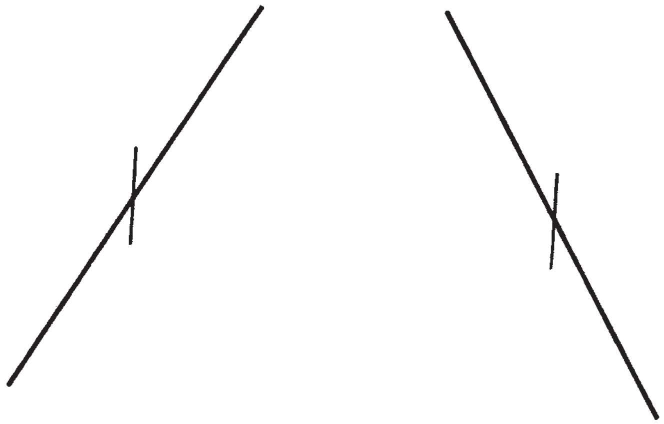

Fig. 3 A contrast illusion for orientation. The two short lines are parallel.

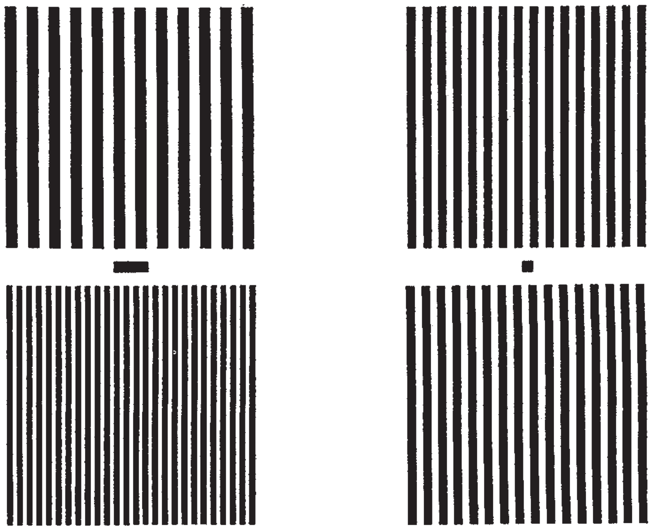

Fig. 4 An after-effect for size. The illusion is best obtained by placing the figure about 1 m away, and looking at the short horizontal bar between the gratings on the left for about 1 min before transferring the gaze to the equivalent spot on the right. (From ref. 2.)

with Fig. 4 (ref. 2). Here, prolonged inspection of the left hand pair of gratings is used to influence our perception of the right hand pair: we come to expect the bars in the upper part of the field to be further apart than those in the lower and hence when we look at two gratings which are the same we judge the bars in the upper one to be closer together than those in the lower.

But the expected value is not determined exclusively by the value of similar stimuli in the environment. The expectation may be influenced also by established correlations which hold between stimuli in one dimension and those in another. A striking example, across sensory modalities, occurs in the "size-weight illusion". Here, an expectation based on visual information affects our judgment of a somaesthetic stimulus. It is a reliable fact about the real world that large objects tend to be heavier than small ones, so that the size an object is seen to be is a potential guide to its weight and the expected weight of the larger of two objects is greater than that of the smaller. Hence if we are asked to lift two objects of different size but of the same actual weight, we judge the larger to weigh less than the smaller—we judge the pound of feathers to be lighter than the pound of lead.

The "depth-size illusion" of Fig. 1 is, to my mind, a phenomenon of this latter kind, where information from one stimulus dimension conditions our expectation about the value of stimuli in another. The nature of the optical projection to the eye is such that more distant objects on the whole give rise to smaller retinal images than near ones, and distance is therefore a guide to retinal size. The expected size of the further of two objects is less than that of the nearer, and hence if we see two lines which appear to be at different distances but have the same actual length, we judge the further to be longer than the nearer.

By this account, the depth-size illusion, the size-weight

Fig. 5 "Midsummer Rest under a Locust Tree"; northern Sung. (Peking Palace Museum.)

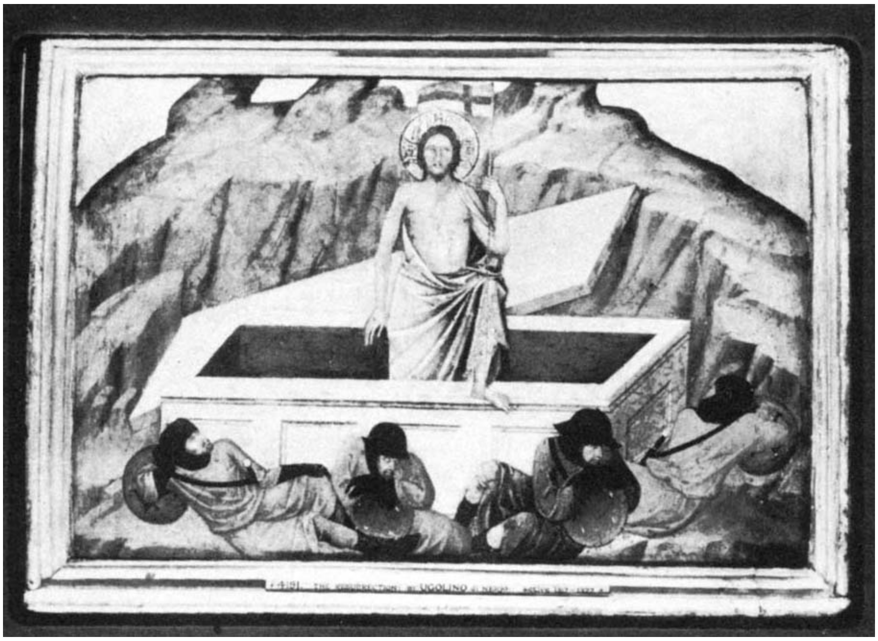

Fig. 6 "Resurrection" by Ugolino di Nerio (National Gallery).

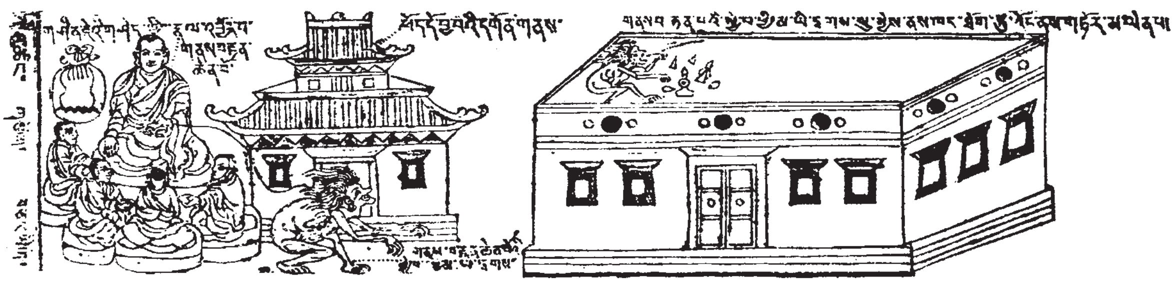

Fig. 7 Illustration from an eighteenth century Mongolian text.

illusion and the illusions shown in Figs. 2–4 are essentially similar phenomena, originating in the contrast between the actual and the expected values.

At a physiological level it is possible that these illusions have a common mechanism. The evidence of electrophysiology suggests that, for many stimulus dimensions, there are nerve units which respond preferentially to stimuli of certain values: any particular stimulus excites a range of such units, to a degree depending on how close their preferred value is to the stimulus's actual value, and the subjective estimate is based on an average of the overall response. The simplest explanation of the illusions is that those units which respond preferentially to the "expected value" are selectively depressed. In the case of the conventional contrast illusions, where the expected value is determined simply by the value of other similar stimuli in the environment, this selective depression would result from adaptation and mutual inhibition among those units excited by such similar stimuli. In the case of the illusions where the expected value is determined by stimuli in another stimulus dimension, the depression would have to involve some kind of cross-dimensional inhibitory interaction.

Whatever fascination these illusions have for scientists concerned with the mechanisms of perception, their importance in practice might seem to be small. To graphic artists, however, the depth-size illusion may cause real trouble. In the painting called "Midsummer Rest under a Locust Tree" from the Peking Palace Museum (Fig. 5) the tenth century Sung artist has drawn the couch on which the philosopher is lying as a perfect parallelogram, with the result that the back in fact looks longer than the front. Again, in the painting of the "Resurrection" from the National Gallery in London (Fig. 6) the Italian Primitive, Ugolino, has done the same with Christ's sarcophagus, and the illusion is present once more. Rather than using the laws of perspective, these artists may well have implicitly followed Princet's suggestion and drawn their material as true to a type instead of true to what they saw: the two sides of a couch, the two sides of a sarcophagus, are equal in reality—and they have been made equal on the page. We may guess that they were puzzled by the distortion which they found, but it would have been in keeping with mediaeval practice to prefer a formal rule to the mundane evidence of the senses.

The same cannot be said, however, of the Mongolian artist who drew the temple in Fig. 7 to illustrate an eighteenth century Bhuddist text. He has drawn the far edge of the temple, which must have been meant to be square, not the same length as, but actually considerably longer than, the near edge. This way of doing things has seemingly no obvious rationale. But we can speculate about its history. What if this artist had innocently modelled his style on examples from the Sung school? He would have been tricked by his eyes into thinking that the Sung painter represented the more distant of two equal lengths as longer than the nearer. What was good enough for the Chinese would have been good enough for him, and in attempting to emulate them he has in fact given concrete expression to what was, unknown to him, the depth-size illusion.

1 Quoted in Waddington, C. H., *Behind Appearance* (Edinburgh University Press, 1969).

2 Blakemore, C., and Sutton, P., *Science*, **166**, 245 (1969).