Leonardo, Vol. 9, pp. 105–110. Pergamon Press 1976 Printed in Great Britain

COLOR PERCEPTION IN ART: BEYOND THE EYE INTO THE BRAIN

Faber Birren*

Abstract—*The author points out that the application of the science of color to art probably had its beginning during the schools of Impressionism and Neo-Impressionism in France. In the 19th century, scientists like M. E. Chevreul, James Clerk Maxwell, Hermann von Helmholtz and Ogden N. Rood fostered new principles drawn from physiological optics. In the 20th century, came Op art that took cues from psychology, but which dealt mostly with optical phenomena, that is, with ways in which the retina and lens of the eye handled color stimuli.*

This article deals with color effects that carry on through the eye itself, up the optic nerve and into the brain, the seat of perception. The brain may well interpret what the eye sees in singular ways. Of particular significance is awareness of the fact, as pointed out by David Katz, that in human vision there is an independent sense of illumination. Exploitation of this sense gives promise of new modes of color expression for the future.

I.

Color has been one of the most intriguing interests of painters since the beginnings of art. For quite a while the mere ability to make pigments and dyes was a major achievement in itself. Then with the freedom offered by tempera and oil vehicles, and scores of new pigments and colorants, painters had their materials under fairly good control and could shift their attention to the esthetics of color, over and beyond the chemistry (and alchemy) of paint making.

Out of the Renaissance came two very important developments—the chiariscuro style of da Vinci and others, and an awareness of aerial perspective. In the chiariscuro style painters do not take pigments and merely add white to them for tints and highlights. Instead, through careful modeling from light to dark, highlight to shadow, the quality of hue was held constant. That is, the highlights were not weak in hue and the deep tones rich—all gradations held the same apparent hue quality. This produced flesh tones that glowed and silks that had amazing sheen and luster. Astonishingly accurate representation was attained.

In aerial perspective, early painters often mixed colors of different quality—from full saturation toward gray—for foreground, middle ground and far distance. Again accurate representation prevailed.

The eyes of painters were on nature. What were her secrets? Long before the days of the science of psychology, painters (and philosopher-scientists) assumed that mysteries were hidden *out there* and needed to be sought and revealed. Later, of course, the realization came that beauty was in the eyes of beholders—humans were the ones whose psyche determined what was beautiful and what was ugly.

Most early works on color involved techniques, beginning, perhaps, with Vasari (1550) who wrote of the styles and methods of da Vinci, Titian and others. There followed valuable works by J. B. Corneille (1648); Gérard de Lairesse (1738); William Hogarth (1753), who suggested an organized palette; J. C. Le Blon (1756), who discovered the primary attributes (in pigments) of red, yellow and blue; Anthony Raphael Mengs (1783), who also pleaded for the neat organization of color, and Moses Harris (*ca* 1766), who published the first known example of a color wheel in actual color.

Well known also in the 18th century were the *Farbensystems* of Ignaz von Schiffermüller (1772), fancifully illustrated in color; *Die Farbenkugel* of Philip Otto Runge (1810), who devised one of the first color order systems in three dimensions, and *Beiträge zur Optik* by Johann Wolfgang von Goethe (1791). Goethe disputed Newton's theory of the physical nature of light and color and declared himself a master of the science of color.

Goethe influenced the English painter Turner and was studied and admired by numerous painters thereafter. While his color hypotheses were quite subject to question, he served the art of color by giving it his personal views and the keen insight of a poet. While his later *Farbenlehre* (1810) had its ups and downs, it has lately been restored to favor as a remarkable work on the psychological aspects of color (before the development of psychology as a science).

* Color consultant, 184 Bedford St., Stamford, CT 06901, U.S.A. (Received 13 March 1975.)

In 19th-century art, color and science truly joined hands. On the traditional and esthetic side was *The Art of Painting in Oil and Fresco* by J. F. L. Merimée (1830 in French, 1839 in English), which had quite a vogue, but it proceeded in the vein of earlier students of the matter, Goethe excepted.

Then, in 1839 came one of the most important of all books on color, *The Principles of Harmony and Contrast of Colors* by M. E. Chevreul, director of the dye houses at the Gobelin tapestry works outside Paris. A monumental work, it established for the artist a wholly new approach to color and in many respects founded the principles of Impressionism. Chevreul dealt with alternate and simultaneous contrast, afterimages and optical mixtures of color and he established 'rules' of color harmony that are still followed today in color and art education.

Delacroix was an admirer of Chevreul and passed this interest on to younger men who were to revolutionize painting with the invention of Impressionism. Chevreul was honored with a statue, a bronze medal and a memorial edition of his masterwork on the occasion of his 100th birthday! His book was kept in print for 25 years. Seventy years after it was published, Robert Delaunay, exponent of Orphism, still paid tribute to it.

In 1879, Ogden N. Rood of Columbia College and the leading authority on physiological optics in the U.S.A. published *Modern Chromatics.* This to a large degree became the 'New Testament' of Neo-Impressionism. Rood inspired scientific studies of light mixtures, drew attention to the scientific findings of Maxwell and Helmholtz. Neo-Impressionism became, perhaps, the most scientific of all schools of color, though it did not last long. Rood's book was studied by Camille Pissarro, Georges Seurat and Paul Signac, while the divisionism of Neo-Impressionism was temptingly considered (and rejected) by Van Gogh, Gauguin, Bernard, Matisse and Derain.

Divisionism, unfortunately, was founded on erroneous and invalid hypotheses. For example, visual mixtures of small dots of color tended to appear gray from a distance due to the inability of the nerves on the retina to distinguish them clearly. (Cf. Rood's book listed in bibliography.) Pissarro, once a convert, became a heretic, confessing that the technique did not suit his temperament and gave 'the impression of the monotony of death'.

II.

With Fauvism, the first Western art movement of the 20th century, conservatism and restraint with color were overthrown. Matisse, Derain and Vlaminck, having the advantage of being able to squeeze pigments out of tubes, applied color 'like sticks of dynamite'. Then came Cubism, which had little interest in color and favored browns.

Farther into the 20th century, Tudor-Hart, a well-known English colorist, had a minor influence. Out of Germany and the Bauhaus came Kandinsky, Klee, Itten and Moholy-Nagy, all of whom were concerned with abstract color expression. There was less science here than personal views that leaned toward the science of gestalt psychology. (Since I edited the works of Albert H. Munsell and Wilhelm Ostwald, two inventors of valuable color systems, I frankly admit that they have had little influence in the so-called 'fine' arts.)

With the advent of Abstract Expressionism around 1950, knowledge and discipline were cast aside. The art of color dropped to its lowest point in art history. Paints were squeezed and poured about on white canvases without much restraint, deliberation or craftsmanship. Acting on impulse and vague 'inner necessity', a struggle for order became a surrender to color chaos.

It is assumed by many painters today that there is little reason to frequent laboratories of physicists, as did the neo-impressionists. Even James Clerk Maxwell, the Scottish physicist, declared: 'The science of color must . . . be regarded as essentially a mental science'. While light energy may stimulate vision and the sense of color, it merely rings the doorbell of the process of vision. After this, unusual things happen. Color, in fact, can be 'seen' without the excitation of wavelengths from the outside. As in dreams, afterimages, a blow on the head, pressure on the eyeball, the effects of certain drugs, such as LSD (in which fountains of dazzling hues are witnessed), the sense of color remarkably operates from within the human brain and psyche.

What is clearly appreciated today is that the experience of color has an amazing degree of independence of external physical facts—as I shall soon explain.

Op art, which followed Abstract Expressionism, led to a return of interest in the science of vision. Now, however, some painters sought counsel from experts in optics and the psychology of perception and used the dazzling effects of red and blue or red and green placed in contrast (the eye cannot focus each component of such pairs at one and the same time), moire patterns, thin lines that prompt sensations of color and 'Mach bands', in which adjacent bands of uniform color seem fluted. Color Field painters, following in the tracks of the Action painters, did little more than place colors in neat and usually geometric patterns—with virtually no other ingenuity. Color Order painters, like Victor Vasarely, demonstrated excellent control of colors and color variations in impressively designed sequences.

Josef Albers at Yale picked up, more or less, where Chevreul had left off. He called attention again to the effects of simultaneous contrast. He elaborated on additive and subtractive color mixtures and the effects of transparency with opaque pigments. He would make different stimuli give the same appearance and similar stimuli give different appearances. He noted in his book, *Interaction of Color:* 'Experience teaches that in visual perception there is a discrepancy between physical fact and psychic effect'.

Yet, Op art concentrated attention chiefly on optics and phenomena associated with optics. Because of this limitation, it rather quickly ran out of material and had a relatively short life.

III.

A new art? Call it 'Perceptionism'. It continues beyond the eye, up the optic nerve into the brain. It is less concerned with what the eye sees literally than with the way in which the brain interprets what is seen. An example of this, in black and white, may be seen in Fig. 1. The science of vision today is becoming increasingly aware of the fact that many visual phenomena are neural. Phenomena such as afterimages, once thought to be of retinal origin, now are being associated with the brain.

Take what is known as color constancy. Why is it that a white surface taken from bright sunlight into a dim room *will still look white*, even though the surface may reflect 1000th as much light? Or why does the side of a white barn in shadow not look gray?

One of the foremost writers on color and perception was David Katz, a German psychologist. His *World of Color*, published in German in 1911, and in English in 1935, ranks in importance to the art of color with the works of Goethe, Chevreul and Rood. Wrote Katz: 'The way in which we see the color of a surface is in large measure independent of the intensity and wavelength of the light it reflects'. With this, Katz opened a new door into color expression.

What is new is recognition that human beings have a definite sense of illumination. And this is an amazing and independent factor in vision. The laboratory of Perceptionism is in the brains of painters. According to Katz: 'With the same immediacy with which we perceive the colors of objects comes the apprehension of their illumination'.

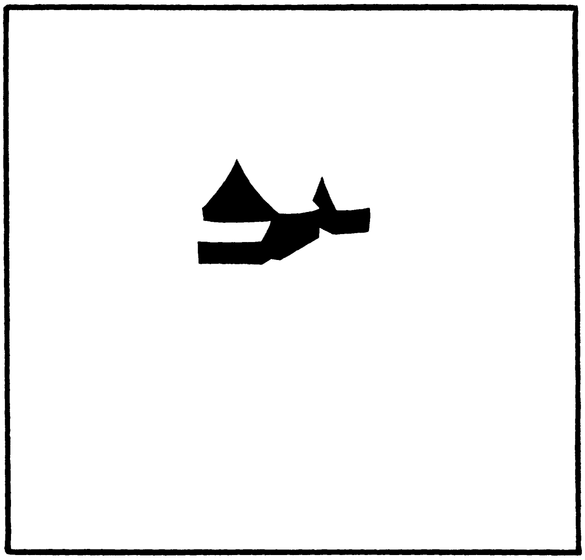


Fig. 1. The term perception in this article refers to inputs to the eyes as interpreted by the brain. These may differ from mere optical effects. For example, in this drawing by the Canadian artist, Marie Kohler, if one 'sees' irregular black areas, this is a result of a mere optical effect. However, if one sees snow-covered farm buildings in a field of snow, this is a result of perception.

This may be confusing (or perhaps academic), for the human sense of illumination is so automatic and natural as to make a person more or less unconscious of it. Perhaps it seldom, if ever, occurs to painters that their works continually look the same, morning, noon and night (under artificial light), in their studios, in a museum or gallery, up on a roof or down in a cellar. This magic is obviously not in the eye; it is in the brain, in perception.

A sense of illumination, as Katz stated, is an independent factor in perception. With even a moderate amount of training, the average person can pretty well determine the brightness level (value, reflectance) of different shades of gray. But who can accurately judge the illumination level of different degrees of light intensity. Ralph Evans, an authority on photography, wrote: 'The eye . . . cannot be used as an adequate meter for illumination intensities'. Yet illumination is always sensed, and chiefly by the appearance of objects and surfaces in the world.

Changes in the pupil opening of the eye, as well as retinal adaptation, definitely contribute to a sense of illumination, but with reservations. With illumination unchanged, for example, the pupil will constrict if exposed to a broad expanse of white and it will expand to a broad expanse of black. Retinal adaptation will also play a role. In life, the eye struggles to strike an average of the brightnesses of surfaces and areas before it. Beyond this, if there is a lot of brightness in objects and surfaces, illumination will *seem* bright; if there are darker values in view, illumination will *seem* dim.

IV.

I shall now discuss a series of black and white pictures and my 'Color Study A'.

Under normal illumination and up close, the world of color is seen in all its 'genuine' hues and values. In the picture of Fig. 2 the shades of gray are scaled from a center white-band square to black-band squares placed on a white background to give the impression of normal illumination. Brightness contrasts are maximum. Such scaling of *chromatic* colors, incidentally, will lead to effects of luster, particularly if hues of strong saturation are used.

In Fig. 3, dim illumination is portrayed using a scale of five steps from white to deep gray. The background is a dark gray. As illumination grows dim, all deep values tend to blend together. Highly saturated colors do not appear as such, but become blackish and muted. Yet white remains white.

In Fig. 4, illumination in an atmospheric mist is simulated with a series of three grays and white. The background is a light gray. Aerial perspective

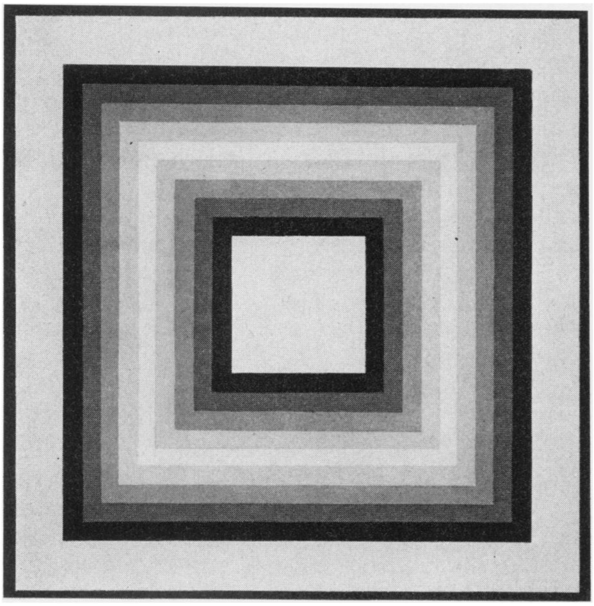


Fig. 2. A picture giving the impression of normal illumination.

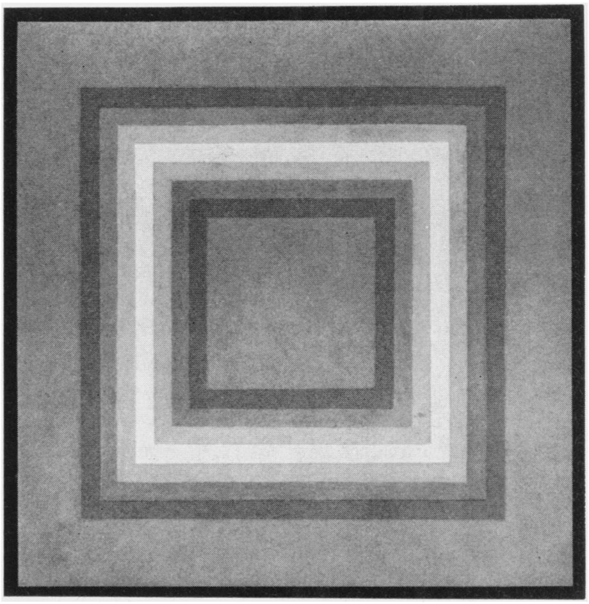


Fig. 4. A picture giving the impression of illumination in an atmospheric mist.

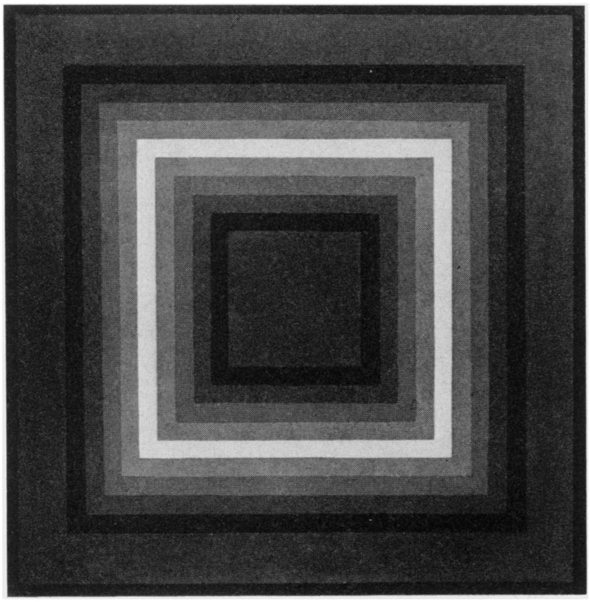


Fig. 3. A picture giving the impression of dim illumination.

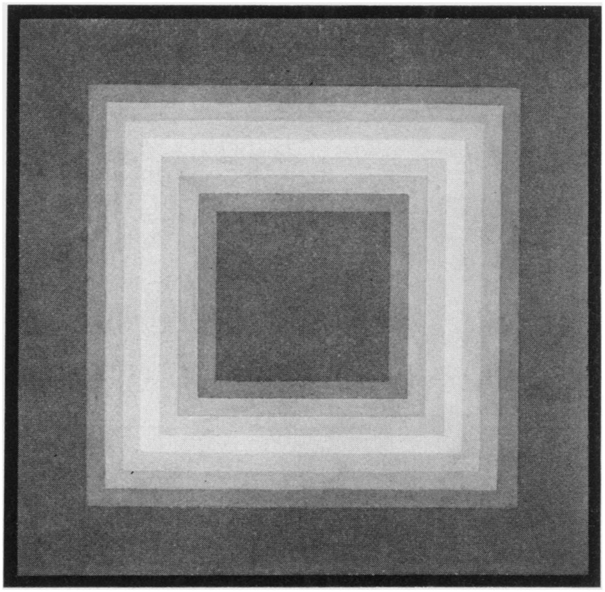


Fig. 5. A picture giving the impression of luminosity.

is involved here. As chromatic colors fall into distance they become grayish in character.

In Fig. 5, an attempt has been made to achieve the effect of luminosity. Again, a series of three grays and white is used, as in Fig. 4, *but the background is a medium rather than light gray*. Luminosity for chromatic colors follows the same principle. In Figs. 2 to 5 the center stripe is the same white.

As a variation of Figs. 4 and 5, a light background gives the impression that illumination is coming from *behind* the gray scale, throwing the scale into shadowy silhouette. This is indicated in Fig. 6.

Many artists in the past have sensed and understood the illumination effects presented and described above and have featured them in naturalistic and representational paintings. There have been impressions of night, sunset and the light of candles. But who in nonfigurative or abstract painting has seriously studied perceptual aspects of vision that go beyond the mere illusions of Op art? There is a new world to conquer here.

V.

David Katz wrote: 'Changes in illumination intensity may easily escape notice, at least more easily than changes in brightness of surface color'. Reversing this, different appearances of illumination may be achieved by controlling and manipulating surface colors. Strong contrast (saturated colors) implies strong illumination. Large areas of subdued color suggest either dim illumination or

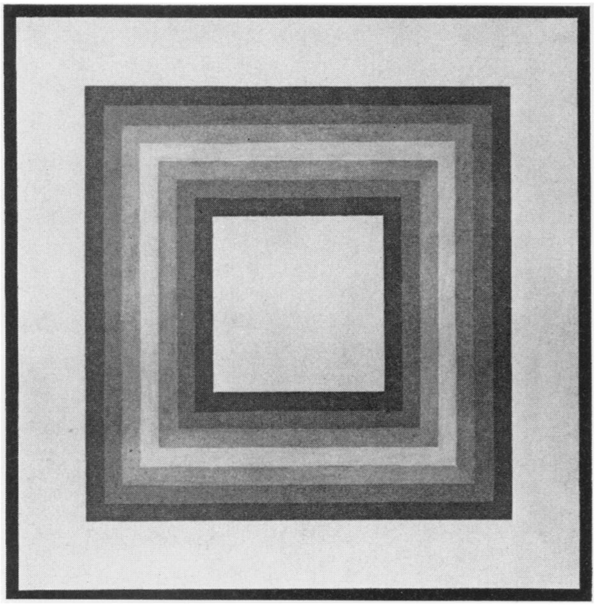


Fig. 6. A picture giving the impression that illumination is coming from behind.

illumination in an atmospheric mist. For paintings, Katz stated: 'The *more* of a picture we perceive, the clearer the impression of the illumination which the artist is representing'. Thus, in a painting seen by the average person from an average distance, the larger canvas holds advantage over the smaller one in causing illusion. 'The color of a small area of a picture signifies nothing in itself; it contributes to the illumination-impression only when it is grasped as part of the whole.' In effect the more the field of view is covered, the greater will be the effect of illumination.

On the matter of color constancy, Katz wrote: 'There seems to be an independence of the colors of objects from the change of illumination'. Consider the following two experiences that would be quite plausible. A gray hen standing in full sunlight in a barnyard and a white hen standing in the shade of the barn would appear gray and white respectively if you witnessed the scene, even though the gray hen reflected more light into your eye than did the white hen. A camera in this instance would record literally all light energy that struck the film. In any such photograph the small patch of the gray hen that stood in sunlight might look white, while the small patch of the white hen that stood in shadow might look gray.

Again, a person may hold a white handkerchief out in the full sunlight. A cloud may pass over the sun, but the handkerchief will still look white. If the person enters a house, goes through a room, down into the basement where illumination is feeble, *the handkerchief will persistently remain white*!

This is color constancy. Katz stated that in bright light white has high 'pronouncedness', while in dim light it has low 'pronouncedness', but the sensation remains white. Perception struggles to see the world as normal under astonishingly varied conditions of illumination. If a sequence of photographs were to be taken of the white handkerchief, as above, the photographer would be kept busy adjusting the lens opening and time exposures of his camera.

Ralph Evans wrote: 'The range of intensities visible to the eye is far in excess of a million to one'. One should appreciate the following point. In nature, brightness differences between the sky and black earth may be of an order of a 1000 to one. In a painting or in a photograph, if an area of white reflects 80 per cent and an area of black 5 per cent, the ratio is a mere 16 to 1. (In color television brightness ratios are usually only 6, 7 or 8 to 1.)

Yet artists have been able to portray sunlight with remarkable conviction. How?

Even more astonishing is the maintenance of color constancy under chromatic light, a phenomenon that defies physics. From dawn to midday to dusk, natural light may vary in tint from pink to orange, yellow, white, pale blue and back again to pink at dusk. A person may be conscious of this change in illumination, but color constancy will prevail and the colors of the world will tend to appear more or less 'normal' anyhow—as if seen under average light.

Even under intense chromatic light, color constancy will persist. M. D. Vernon wrote: 'Again, a white surface in a red light [i.e., a red-producing light] may up to a point appear less red than a red surface in white illumination, even when the former reflects more red light than the latter'. While there is greater constancy to differences in the intensity of white light, nevertheless constancy under chromatic light is amazing.

'Color Study A' (Fig. 7, cf. color plate), illustrates color effects in which illumination in red, yellow, green and blue is portrayed. How were these schemes developed?

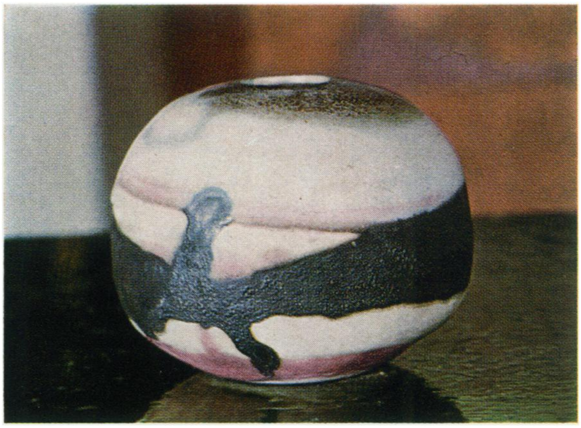
A range of colors of full saturation, in red, yellow, green, blue, violet, white and black, was set up on a chart. The colors on the chart were then viewed under tinted light (or more conveniently, as seen through dyed cellophane or theatrical gelatin). The colors thus seen were then matched in front of the chart and under normal 'white' illumination. The palette so adjusted was then used to carry out the four areas in 'Color Study A'. The picture demonstrates that perception converts to the appearance of tinted light what originally were mere paints (or printing inks in the reproduction). The magic of color constancy is exploited.

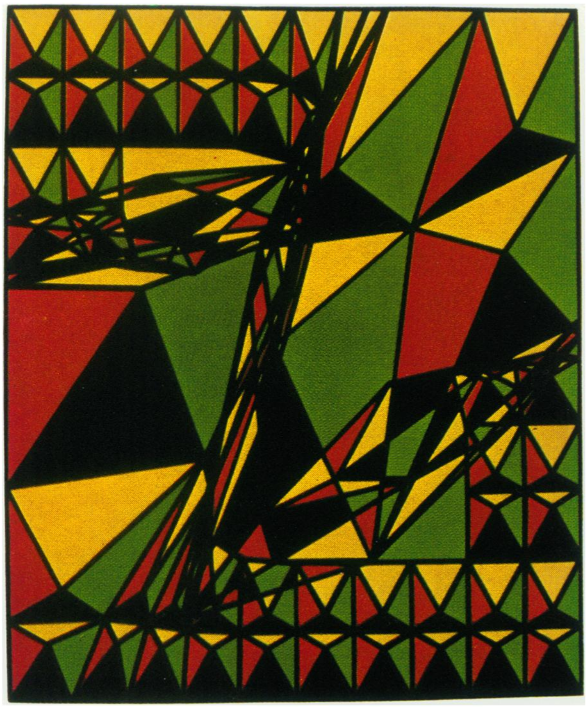
BIBLIOGRAPHY

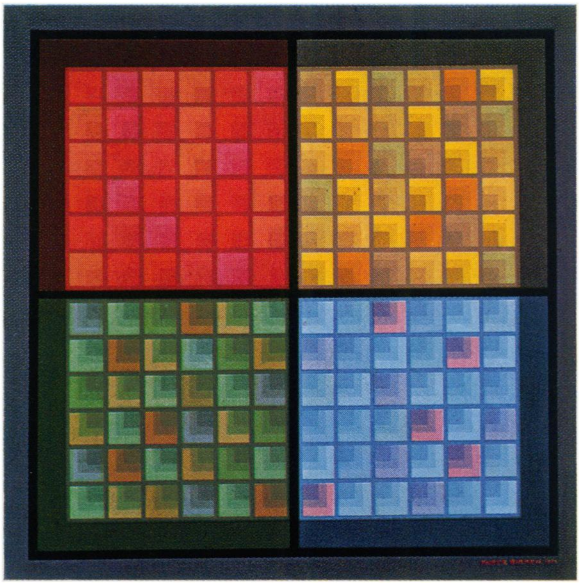
I have consulted dozens of books and articles, over many years, previous to writing this paper. Because these are too numerous to include here, I give the following selected references:

1. J. Albers, *Interaction of Color* (New Haven, Conn.: Yale University Press, 1971).
2. R. Arnheim, *Art and Visual Perception* (Berkeley and Los Angeles, Calif.: University of California Press, 1957).

3. J. Beck, *Surface Color Perception* (Ithaca, N.Y.: Cornell University Press, 1972).
4. F. Birren, *Monument to Color* (New York: McFarlane, Warde, McFarlane, 1938).
5. F. Birren, *Creative Color* (New York: Reinhold, 1961).
6. F. Birren, *History of Color in Painting* (New York: Reinhold, 1965).
7. F. Birren, ed., *The Principles of Harmony and Contrast of Colors*, Michel Eugène Chevreul (1839) (New York: Van Nostrand Reinhold, 1967).
8. F. Birren, ed., *Modern Chromatics*, Ogden N. Rood (1879) (New York: Van Nostrand Reinhold, 1973).
9. R. Evans, *The Perception of Color* (New York: John Wiley, 1974).
10. J. J. Gibson, *The Perception of the Visual World* (Boston, Mass.: Houghton Mifflin, 1950).
11. C. H. Graham, *Vision and Visual Perception* (New York: John Wiley, 1965).
12. R. L. Gregory, *The Intelligent Eye* (New York: McGraw-Hill, 1970).
13. D. Katz, *The World of Color* (London: Kegan Paul, Trench, Trubner, 1935).
14. G. Murch, *Visual and Auditory Perception* (New York: Bobbs-Merrill, 1973)
15 J. J. Shephard, Jr., *Human Color Perception* (New York: Elsevier, 1968).
16. M. D. Vernon, *The Psychology of Perception* (Harmondsworth, England: Penguin Books, 1966).







Top left: *David A. Hardy. 'Enigma', acrylic paint on paper board*, 20 × 36 in, 1970. (Fig. 5, cf. page 96.)

Top right: *Gregg Conway. Bottle, porcelain*, height 5 in, diam. 6 in, 1972. (Photo: M. Belin, Paris.) (Fig. 2, cf. page 91.)

Bottom left: *Ruth Leavitt. 'Prismatic Variation, II', serigraph*, 29 × 23 in, 1974. (Fig. 5, page 102.)

Bottom right: *Faber Birren. 'Color Study A'. A picture illustrating color effects in which illumination in red, yellow, green and blue is portrayed.* (Fig. 7, cf. page 109.)