COGNITION THROUGH COLOR

JULES DAVIDOFF

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I know how to react if you tell me that you have seen a white or a pink elephant.
Umberto Eco

Foreword

Long Live VIBGYOR!

John C. Marshall

Our lives are informed by color at all levels, from the most utilitarian (stop at the red light) to the most metaphorical (a colorful personality). Yet we have little difficulty in imagining (or seeing) a world without color—at night, all cats are gray, and many of us prefer black-and-white photography to garish technicolor. Nonetheless, the ubiquitous presence of (daytime) color experience, and our varied ways of talking about it, carve out a domain of scientific inquiry that is (paradoxically) both highly constrained and coextensive with human cognition.

Little wonder, then, that the study of normal color cognition should, for many centuries, have exercised the minds of physicists, physiologists, psychologists, and linguists (to say nothing of artists, interior decorators, and those nameless creatures who nowadays add artificial coloring to our apple pies). The prismic observation of Isaac Newton (1704) that a beam of white light can be separated into a spectral band of colors is easy enough to replicate; but the poet who fondly imagines drinking *white* wine by the banks of the *blue* Danube is indulging in poetic license. As indeed was Newton himself when he "saw" "only seven separate homogeneal colors" (Boring, 1942) dispersed on the screen by his prism. The percept VIBGYOR (violet, indigo, blue, green, yellow, orange, and red) may have owed as much to linguistics as it did to visual sensation (Berlin and Kay, 1969). As an exercise in understanding the relationship between biology and culture, the investigation of color has proved remarkably successful.

The basic mechanisms of color vision should be universal across all (normal) members of the human species, although subject to limited parametric variation consequent upon "environmental adaptation to ultraviolet components in sunlight and/or dietary habit" (Bornstein, 1973). On the other hand, languages have such varied color-naming systems that it was (once) possible to believe that "words for basic colors are not translatable across languages, and that each language expresses color perception in arbitrary color words" (Ratliff, 1976). Yet one (of many) exciting conclusions from recent study is that "the linguistics of color terms *corroborate* the neurophysiological basis of the opponent color theory; they do not conflict with it" (Von Wattenwyl and Zollinger, 1979). Even for those whose primary interest is *not* in color cognition, the topic may well provide a salutary example of an unbroken explanatory chain from the retina (Dowling, 1987) to language as a mirror of the mind (Chomsky, 1966).

That chain can, however, be broken by brain damage, thereby causing (relatively selective) deficits that range all the way from disorder of color discrimination to disorder of color naming and memory. As in all other domains of human neuropsychology, the fractionation of color cognition by discrete cerebral injury has provided important constraints on the theory of normal functioning (Shallice, 1988).

Central achromatopsia, with well-preserved acuity, was first observed by Robert Boyle (1688) and has subsequently continued to provide crucial evidence for the modular structure of early processing mechanisms (Mollon, Newcombe, Polden, and Ratcliff, 1980; Heywood, Wilson, and Cowey, 1987). At "higher" levels of processing, we seem to need a large range of distinctions between and within such taxonomic categories as color agnosia (Kinsbourne and Warrington, 1964), color anomia (Oxbury, Oxbury, and Humphrey, 1969), and color amnesia (Varney, 1982). There is a bewildering variety of color-tasks that patients without primary loss of color discrimination can and cannot perform (Lewandowsky, 1908; Meadows, 1974; Beauvois and Saillant, 1985). "Knowledge" of colors is distinct from perception thereof. The patient who no longer knows that grass is (typically or paradigmatically) green is not suffering from a perceptual disorder; and likewise the patient who can accurately sort tokens of varied hues into conventionally acceptable categories, but calls the green ones red.

Jules Davidoff's *Cognition through Color* covers (in brief outline at least) most of the spectrum of scientific knowledge of color, from the cones and ganglion cells of the retina to the child's acquisition of color vocabulary. And at most points along the way, a serious integration of studies of normal and impaired color perception is attempted. To achieve this breadth of coverage *and* include full details of everything that is currently known about color would, of course, require a hundred-volume encyclopedia (and even more authors than volumes).

The structure of Davidoff's (one-volume) book is accordingly of some consequence. What he has written is actually an essay concerning the neuropsychology of object recognition. At first blush, this might appear to extend the scope of the monograph to a ridiculously broad extent: color cognition *and* object recognition! The careful reader will, however, soon see that the object of the exercise is to restrict the core of the monograph to a domain that is both manageable and theoretically motivated.

The organization of the brain appears to be such that initial input stages are characterized by separate channels or streams for such "stimulus" properties as shape, size, orientation, motion, depth, color. . . . But the organism as a whole will usually have little interest in these properties per se. What the "ego" wants to know is what is out there (and where out there is it, and what is it doing). It is this information that allows the subject to plan and execute an appropriate response to the environment. And it is in this sense that Davidoff's monograph is concerned with the role that color plays in object recognition. The shape of the text concerns not color but rather the colors of *things*: how they are seen, represented in memory, talked about (and otherwise responded to).

It is thus my conviction, then, that the new theory of color cognition in Davidoff's book cuts nature at the joints. I accordingly expect that this monograph will play an important role in stimulating and steering further advances in the cognitive neuropsychology of color.

References

Beauvois, M.-F., and Saillant, B. (1985). Optic aphasia for colours and colour agnosia: A distinction between visual and visuo-verbal impairments in the processing of colours. *Cognitive Neuropsychology* 2: 1–48.

Berlin, B., and Kay, P. (1969). *Basic Color Terms: Their Universality and Evolution*. Berkeley: University of California Press.

Boring, E. G. (1942). *Sensation and Perception in the History of Experimental Psychology*. New York: Appleton-Century.

Bornstein, M. H. (1973). Color vision and color naming: A psychophysiological hypothesis of cultural difference. *Psychological Bulletin* 80: 257–285.

Boyle, R. (1688). *Uncommon Observations about Vitiated Sight*. London: Taylor.

Chomsky, N. (1966). *Cartesian Linguistics*. New York: Harper and Row.

Dowling, J. E. (1987). *The Retina: An approachable part of the brain*. Cambridge, Mass.: Belknap Press.

Heywood, C. A., Wilson, B., and Cowey, A. (1987). A case study of cortical colour "blindness" with relatively intact achromatic discrimination. *Journal of Neurology, Neurosurgery, and Psychiatry* 50: 22–29.

Kinsbourne, M., and Warrington, E. K. (1964). Observations on colour agnosia. *Journal of Neurology, Neurosurgery, and Psychiatry* 27: 296–299.

Lewandowsky, M. (1908). Ueber abspalting des farbensinnes. *Monatsschrift für Psychiatrie und Neurologie* 23: 488–510.

Meadows, J. C. (1974). Disturbed perception of colours associated with localized cerebral lesions. *Brain* 97: 615–632.

Mollon, J. D., Newcombe, F., Polden, P. G., and Ratcliff, G. (1980). On the presence of three cone mechanisms in a case of total achromatopsia. In G. Verriest, ed., *Colour Vision Deficiencies*, Vol. 5. Bristol: Hilger.

Newton, I. (1704). *Opticks*. London: Smith.

Oxbury, J. M., Oxbury, S. M., and Humphrey, N. K. (1969). Varieties of color anomia. *Brain* 92: 847–860.

Ratliff, F. (1976). On the psychophysiological bases of universal color terms. *Proceedings of the American Philosophical Society* 120: 311–330.

Shallice, T. (1988). *From Neuropsychology to Mental Structure.* Cambridge: Cambridge University Press.

Varney, N. R. (1982). Color associations and "color amnesia" in aphasia. *Journal of Neurology, Neurosurgery, and Psychiatry* 45: 248–252.

Von Waltenwyl, A., and Zollinger, H. (1979). Color-term salience and neurophysiology of color vision. *American Anthropologist* 81: 279–288.

Preface

The starting point of *Cognition through Color* was a patient who was referred to me when I was working in the MRC Neuropsychology Unit at the University of Oxford. One of the patient's problems was an inability to name colors. More than that, despite normal color vision, his memory for colors and the colors of objects was "split off" from all other aspects of his memory. The patient's memory for shapes of objects was excellent, but he could not recognize their colors. Color would thus appear to qualify as one of the basic building blocks—input modules—from which perception is constructed and our memories organized. A research program was subsequently initiated, the consequence of which is *Cognition through Color*.

Modular input is compatible with some approaches to the study of perception but not to other philosophical and experimental accounts. To the latter, a color cannot exist without being the color of something. My own work with normal individuals also raised doubts concerning modularity. While there indeed appeared to be several tasks in which, perhaps counterintuitively, color played little role; for object-naming tasks, color was beneficial. Thus it became clear that in order to understand how color is remembered, we must know how objects are identified. The book, therefore, develops a model in which the understanding of objects is linked to the knowledge concerning their color.

Cognition through Color is, like most academic texts, mainly a summary of other people's research effort. Wherever possible, ignorance and sloth permitting, I have tried to give credit to the originators of ideas or lines of research. To those whose ideas have been omitted or misrepresented I apologize. There is also thanks to be expressed for help given. The excellent recent texts that have become available were particularly useful in getting color into a more general perspective of object recognition. Without them, the inaccuracies would assuredly have been greater. There are individuals whom I would like to thank by name. They read parts, sometimes only a few pages, and by so

doing made significant improvements to them. I am, therefore, extremely grateful to Chris Barry, Patrick Cavanagh, Ilham Dilman, Jon Driver, Julie Evans, Charlie Heywood, Kathy Mullen, Keith Ruddock, Rodger Weddell, and Sean Wilkie. There are some individuals whom I cannot thank by name, as they were the anonymous reviewers of earlier drafts for MIT Press. To those people I owe a great debt. Gratitude must also be extended to the conscientious attention to the draft manuscript given by the series editor, John Marshall. It was through his good efforts that I was able to spend a few months at the Université de Montreal, and it was there that the first few stabs were made at the keyboard. To Roch Lecours and all others there who provided such excellent facilities, I would like also to express my gratitude. For some obscure reason, the emblem of their lab is a pink elephant.

Contents

Chapter 1
Introduction

1.1 *An Object Lesson*

When phrenologists (bump readers) had their heyday in the nineteenth century, their diagram of faculties included a bump for color, situated just above the eyebrow. Today, the notion of a color center has returned, but its locus is considerably different. The site of the color center or color module, to give the contemporary terminology, is at or near the visual cortex. The phrenologists' argument was based on spurious correlations; the modern modular approach to the organization of the visual cortex (Zeki, 1978; Cowey, 1985) is considerably more sophisticated. However, the essence is the same. All modular descriptions hold that there are brain areas solely dedicated to particular aspects of perception; these modules include not only color but also those for the analysis of motion, stereopsis, and shape. The critical word is *solely*. In a modular system, these brain areas are computationally autonomous. They are, as Fodor (1983) describes them, informationally encapsulated. Indeed, part of the credit—if credit is the right word—for the widespread acceptance of modular input systems within neurophysiology must be given to Fodor's philosophical account. As part, albeit not the most significant, of his influential thesis ("Modularity of Mind"), he allows *input* modules a substantial place. Fodor writes (p. 132): "Generally speaking, the more peripheral a mechanism is in the process of analysis . . . the better candidate for modularity it is likely to be. . . . There is recent, striking evidence owing to Treisman and her colleagues that the detection of such stimulus "features" as shape and color is typically parallel, preattentive, and *prior* to the identification of the object in which the features, as it were inhere. . . . There is analagous evidence for the modularity of (other) detectors. . . ." It is such claims with respect to color that are considered and rejected in the first chapters of this book. Other (noninput) versions of modularity are not rejected. Indeed, in subsequent chapters a proposal of functional modularity will emerge that has relevance to a psychological understanding of object knowledge and its mental representation.

Input modules have their historical roots in the philosophical tradition of Locke, which breaks down objects into separate sensations of shape, motion, color, and the like. The neurophysiological instantiation of that tradition requires evidence for a separate pathway from which those sensations might arise. Its genesis has been detected in the writing of Newton (Hilbert, 1987). Newton wrote, ". . . so colours in the object are nothing but their dispositions to propagate this or that motion into the sensorium, and in the sensorium they are sensations of those motions under the forms of colours." However, the status of Newton's version of color perception is unclear with respect to modularity. More than generalized brain activity is required for a system to be described as modular. Before arriving at even a simple modular input account, brain activity needs to be organized by, for example, Mueller's (or perhaps more properly Elliot's see Mollon, 1987) principle of the specific energies of nerves. Only by such means could one imagine a processing system solely dedicated to color. Or, at least, one could try to imagine it. The difficulty would come in imagining a color that had no extent (spatial constraint). Thus, inherent in the straightforward modular account of color perception is the problem of how color is integrated with other stimulus aspects. As John Stuart Mill put it (Westphal, 1987, p. 109), "whatever hidden links we might detect in the chain of causation terminating in the colour, the last link would still be a law of colour, not a law of motion nor of any other phenomenon whatsoever." The problem of how modules might be integrated is addressed in the opening chapters of this book.

The philosophical tradition that holds objects rather than sensations to be basic for perception (Strawson, 1979) provides a potential solution to the problem of integrating modular inputs. Historically, one can see Goethe's refusal to divide color into parts as being in that tradition. Goethe (see Ribe, 1985) said upon conducting the Newtonian experiment of projecting light through a prism: "How astonished I was that . . . no trace of coloring was to be seen on the light grey sky outside. It did not require much deliberation for me to realize that a boundary is necessary to produce colors, and I immediately said aloud to myself as if by instinct that the Newtonian theory was false." Goethe took as his primary percept (*Urphaenomen*) the color of a surface rather than Newton's spectral colors. A surface is not possible without a boundary; hence, Goethe believed that color is an edge phenomenon. In the spirit of Goethe, Westphal (1987) talks not of color but of "being coloured" as a property of colored things. The proposal that color was a property of surfaces was greeted with ridicule by color theorists working in the Newtonian tradition. On reviewing Goethe's work, Young (1814) denigrated it as follows (Ribe, 1985): "Our attention has been less directed to this work of Mr. von Goethe, by the hopes of acquiring from it anything like information, than by a curiosity to contemplate a striking example of the perversion of the human faculties." Goethe's observations are not so easily dismissed; they are intrinsic to theories of color perception concerned with color contrast (Hering, 1964; Land, 1977). However, to be fair to Newton, it is worth recording (Mollon, 1988) that color-contrast phenomena were documented prior to Goethe's outburst. Goethe was aware of these reports; thus, his observations did not have quite the originality he claimed for them.

There must be considerable sympathy for the philosophical position that has a "commonsense" preference for a world of objects rather than giving primacy to isolated input modules (Kelley, 1986). We are not aware of color, depth, and motion but of their combination in objects; thus, attempts to analyze perceived objects into discrete features by distinct independent modules can be regarded as artificial. However, textbooks on the psychology of color perception provide examples of supposedly pure color percepts (Beck, 1972). For example, a red light viewed through a small aperture fills the aperture with a so-called film color that appears to be at an indeterminate distance from the observer. The film percept is in contrast to most of our day-to-day percepts, where it is completely clear that the color is at the surface of an object. There are exceptions—the sky, for example—but these are few. Although the same name (red, green, and the like) can be applied to both film and surface colors, the two percepts are different. Film colors are luminous (i.e., they glow) or are transparent; surface colors are, almost always, nonluminous and opaque. When intensity is increased, a film color becomes luminous, never shiny, as does a surface. Katz (1935) says that spectral (film) colors are always seen in a vertical plane to the observer and often at an indeterminate distance; surface colors are seen at any orientation but at a particular place. The colors of objects are surface colors, but the background, according to Rubin (1921), has a film appearance; the film color is the "smooth or space-filling quale" of Hering (quoted in Katz, 1935).

We argue that neither film nor surface color is *pure* color. Following many others (see Kelley, 1986) we maintain that there can be no sensation of red, only the perception of a *red object;* even film color has a location in the visual field and is, in principle, no different from other examples of color. Kelley's argument can be extended to colored surfaces that are transparent or glow with color. These sensations are