Color categories in thought and language

edited by C. L. Hardin
Syracuse University

Luisa Maffi
University of California at Berkeley

CAMBRIDGE
UNIVERSITY PRESS

Published by the Press Syndicate of the University of Cambridge
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
40 West 20th Street, New York, NY 10011-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

First published 1997

Designed in Quark XPress, FF Thesis and Swift

A catalogue record for this book is available from the British Library

Library of Congress cataloguing in publication data
Color categories in thought and language / edited by C. L. Hardin and
Luisa Maffi
p. cm.
Based on papers presented at a conference, Asilomar Conference Center,
California in 1992.
Includes index
ISBN 0 521 49693 4 (hardback) – ISBN 0 521 49800 7 (paperback)
1. Color–Psychological aspects. 2. Color vision–Cross-cultural
studies. 3. Psycholinguistics. I. Hardin, C. L., 1932–
II. Maffi, Luisa.
BF789.C7C585 1997
152.14'5–dc20 96-7898 CIP

ISBN 0 521 49693 4 hardback
ISBN 0 521 49800 7 paperback

Transferred to digital printing 2002

SE

Contents

1 Introduction

C. L. Hardin and Luisa Maffi

Do visual science and anthropological linguistics have anything to say to each other? Does the makeup of the human color-vision system constrain the linguistic expression of color categories in any interesting ways? Does the way we use color language suggest anything about the biological organization of color vision? In the early 1950s, an open-minded reading of the relevant scientific literature would have offered scant reason to answer such questions affirmatively. Color scientists concerned themselves with color matching and discrimination, adaptation, and the measurement of thresholds, but said little about the categorical structure of color appearance. For their part, anthropological linguists had long since put behind them earlier attempts to arrange systems of color naming in evolutionary schemes from "primitive" to "developed," or to relate the paucity of color words in some languages to color-vision deficiencies in the peoples who spoke them. Indeed, the supposed arbitrariness with which various languages divided color space came to be taken as paradigmatic not only of cultural relativity, but of the capacity of language to shape the perceptions of its speakers.

Hering's opponent-process theory

A pronounced sea-change in the thinking of visual scientists began in 1955 with a series of papers in which Leo M. Hurvich and Dorothea Jameson advanced a quantitative opponent-process theory. A qualitative version of the theory had earlier been propounded by Ewald Hering, who claimed on introspective grounds that there are two perceptually elementary achromatic colors, black and white, and four perceptually elementary chromatic colors, red, yellow, green, and blue, all other colors being seen as perceptual blends of those six. Furthermore, said Hering, our failure to see red-greens or yellow-blues tells us that the color-vision system, like many other bodily systems, must be set up in antagonistic fashion, with red opposed to green and yellow opposed to blue. (The achromatic colors are a bit different. Although black is inversely related to white, it is not fully incompatible with it: a particular gray can always be described in terms of its percentage of either whiteness or blackness.) The framework of opponency enables one to make ready sense of many details of a variety of visual processes, including simultaneous and successive contrast, chromatic adaptation, and color deficiency.

Hering's theory was rejected by most visual scientists for three reasons. (a) A qualitative theory does not lend itself well either to elaboration or to test, whereas the existing Young–Helmholtz trichromatic theory could be quantitatively formulated, and this led to many useful experimental results. Furthermore, Hering's account rested on introspective data, and introspective methods had long since proved themselves to be not only controversial but also fruitless. (b) Hering called for four elementary chromatic processes, and this was understood as an assertion that there are four types of color receptors. However, abundant behavioral and physiological data made it clear that there could be but three. (c) The Hering opponent processes called for antagonistic responses on either side of a neutral point, so that when the red and green responses, for example, were equally excited, the net result would be a null response, experienced as achromatic. However, the then-known responses of sensory neurons were of the all-or-none variety, and it was difficult to see how a configuration of such neurons could support a system requiring bipolar graded responses.

The advent of the microelectrode made it possible to record the responses of individual neurons *in vivo*. Svaetichin discovered visual neurons in fish that displayed graded responses, and shortly thereafter it was shown that ganglion cells in primate retinas vary their firing rates as a function of wavelength. Direct recordings from primate lateral geniculate nucleus cells suggested that they have some of the response properties required by the four elementary Hering processes. Taken together, these discoveries undercut not only the third objection, but the second as well. This objection, Hurvich and Jameson pointed out, was based on a misreading of Hering, who had never claimed that the four elementary chromatic *processes* required four types of *receptors*. What Hurvich and Jameson proposed was a two-stage configuration, with a first stage consisting of short-, middle-, and long-wave receptors that were cross-connected to yield a second, opponent stage, consisting of red–green, yellow–blue, and white–black channels. Hurvich and Jameson's theory, like Hering's, was psychophysical in character, with opponent channels defined functionally rather than anatomically. However, by making the theory quantitative, Hurvich and Jameson could begin to impose constraints that any putative set of neural mechanisms subserving color vision would have to satisfy.

As Wooten explains in greater detail later in this volume, by asking a subject to cancel the chromatic appearance of one monochromatic beam of light by adding another beam to it, Hurvich and Jameson were able to establish the relative strengths and null points of the subject's chromatic responses, and thus to derive a chromatic response function for that subject. From this they could calculate with fair accuracy other psychophysical responses, such as the subject's wavelength discrimination and saturation functions. The procedure was replicable, reliable, and made minimal appeal to introspection (the instructions were sophisticated variants of the form: "Turn this knob back and forth until what you see looks neither yellowish nor bluish," or "Turn the knob until all the redness disappears."). The first objection to the Hering scheme was thus met as well, and opponent-process theory became a cornerstone of color-vision research.

Berlin and Kay's *Basic Color Terms*

The sea-change in anthropological linguistics came in 1969 with the publication of Brent Berlin and Paul Kay's *Basic Color Terms*. Berlin and Kay were struck by the ease with which common color terms could be translated between languages from locales as diverse as Tahiti and Mesoamerica. If, however, as the then-prevailing wisdom held, languages divide color space arbitrarily, and moreover shape the way that their speakers perceive colored objects, how was this possible? To investigate the question, Berlin and Kay proposed criteria to separate the basic from the non-basic color terms of a language. Basic terms were to be those that were *general* and *salient*. A term is general if it applies to diverse classes of objects and its meaning is not subsumable under the meaning of another term. A term is salient if it is readily elicitable, occurs in the idiolects of most speakers, and is used consistently by individuals and with a high degree of consensus among individuals. To determine the reference of the basic color terms of a language, Berlin and Kay employed a rectangular array of Munsell color chips of maximum available relative saturation (Chroma), vertically ordered in ten equal lightness (Value) steps, and horizontally ordered by hue (Hue), each column differing from its neighbors by a nominal 2.5 Hue steps. (The array, a representation of which appears on the cover of this book, is essentially a Mercator projection of the outer skin of the Munsell solid – cf. the frontispiece.) The test array was covered by transparent acetate, and each participant was asked, for each basic color term, to mark with a grease pencil (a) the best example of the color, and (b) the region of chips that could be called by the color term.

The investigation on which *Basic Color Terms* was based used native speakers of twenty languages who resided in the San Francisco Bay Area, supplementing this limited field study with a literature search on seventy-eight additional languages. The *synchronic* results were that languages varied in numbers of basic color terms, from a minimum of two terms (Papuan Dani) to a (probable) maximum of eleven, Russian and Hungarian being possible exceptions; but no matter how many basic color terms languages might have, their foci reliably tended to cluster in relatively narrow regions of the array, whereas boundaries were drawn unreliably, with low consistency and consensus for any language.

The *diachronic* conclusion was that if languages were ordered according to numbers of basic color terms, the sequence of encoding of foci was tightly constrained. (Berlin and Kay subsequently abandoned their conception of successive *encoding* of foci in favor of the idea that the steps represented the progressive *division* of the color space, yielding three types of basic categories: composite, fundamental, and derived; cf. Kay, Berlin, Maffi, and Merrifield, this volume.) For example, if a language has two basic color terms (a "Stage I" language), those terms will encode black and white. If it has three ("Stage II"), those terms will encode black, white, and red. If it has four ("Stage III"), the terms will be for black, white, red, and either yellow or green. The entire sequence, as originally conceived, comprised seven stages and eleven basic color terms.

Berlin and Kay interpreted this as an evolutionary sequence. Their claim was controversial for two reasons. First, because, if it were correct, this would be one of the few instances in which linguistic development proceeds unidirectionally from simplicity to complexity. Second, because it readily suggested to some the now-taboo late-nineteenth-century picture of an evolutionary culture chain, with Papua New Guineans at the bottom, scarcely a step above the beasts, and sophisticated Europeans situated comfortably and properly at the top. This second reading, however much it may have affected the subsequent reception of the Berlin–Kay theses in certain quarters, was no part of the authors' perspective, and will be given no further attention on these pages.

Linkages

The connection between the findings of *Basic Color Terms* and Hering's opponent-process theory did not escape Berlin and Kay. Hering's elementary red is of *unique* or *unitary* hue, i.e., it is a red that is neither yellowish nor bluish. Unique green is likewise neither yellowish nor bluish, and unique yellow and blue are neither reddish nor greenish. Unique red (or unique green) appears whenever the red–green process is positive (or negative) and the yellow–blue process is at a null point. Similarly, unique yellow (or unique blue) is seen whenever the yellow–blue process is positive (or negative), and the red–green process is at a null point. All other hues, such as orange or purple, are seen when both processes are active. Orange is thus perceived as a red–yellow and purple as a red–blue blend (or *binary*). The Berlin–Kay focal reds, yellows, greens, and blues have hues that are close to the average unique hue points, as casual inspection of the Munsell chips suggests and as Chad McDaniel established experimentally. Moreover, since red, yellow, green, and blue are perceptual ingredients in every chromatic color, one would expect them to be more salient than any of the blends. Lightness and darkness are of course the most salient visual experiences, and so we would anticipate that they would be encoded first in the Berlin–Kay developmental sequence. Red, yellow, green, and blue follow in more or less that order. That they as a group should be labeled before the colors of binary hue comes as no surprise, but Hering's theory offers us no explanation for the particular order of their appearance. Nor does opponent-process theory help us to understand many other features of the Berlin–Kay evolutionary sequence, or, for that matter, several of the synchronic results. Why, for example, are red–yellow and red–blue binaries represented (orange and purple), but not yellow–green (chartreuse) or green–blue (turquoise)? Examples could be multiplied. Opponent processes are far from being all there is to the study of color vision, and one might hope to gain further insight into such aspects of the linguistic domain of color by further investigations into the phenomenology and mechanisms of seeing.

In an important study published in the *Journal of the Optical Society of America* in 1966, DeValois, Abramov, and Jacobs flashed colored lights before the eyes of macaque monkeys while simultaneously recording the responses of individual lateral geniculate nucleus cells. The LGN, part of the thalamus, is an intermediate point on the optic pathway that leads from the retina to the primary visual cortex in the brain. LGN cells are closely similar in response to ganglion cells, which are the last cells in the retinal processing chain (the photoreceptors are the first). The DeValois team sampled the spectral responses of 147 cells, grouping them into four classes according to the spectral wavelength that caused them to cross over from excitation to inhibition, and labeled these groups as the +R−G, −R+G, +Y−B, and −Y+B cells respectively. At the time, these seemed to be promising candidates for the neural substrates of Hering's processes. Berlin and Kay took this to heart, and, frequently citing the DeValois *et al.* paper, called red, yellow, green, and blue categories the "neural primaries." As Abramov shows in his contribution to the present volume, this is now understood to be in error: the LGN cells cannot be the sites of the Hering elementary processes, although they mark a very important stage in opponent processing. Those sites must be found further upstream, in the cortex; the matter is being actively investigated.

In the two decades since the original publication of *Basic Color Terms*, much has happened in the study of color vision and in the elaboration, criticism, and modification of the Berlin–Kay theses. More is now known about the neurophysiology of color vision, and there is a new appreciation of its puzzles and complexities. Color-naming techniques have been developed and shown to track closely the subjects' chromatic response functions. Color categorization has been more systematically explored using alternative color-order systems, such as the Optical Society of America–Uniform Color Space and the Swedish Natural Color System, and much wider samplings of color space. These have in turn been suggesting constraints on the physiological mechanisms of color perception. The cross-cultural data base for color-term use has been vastly expanded, with Robert MacLaury's Mesoamerican Color Survey as well as the Berlin–Kay–Merrifield World Color Survey. Berlin, Kay, McDaniel, and others have contributed to revised theoretical accounts, while MacLaury has devised a theory of the dynamics of color-term development. The fundamental assumptions and methods of the Berlin–Kay tradition have been questioned by several critics, and the nature and limits of the enterprise are being clarified as a result. Finally, new ideas and techniques are being introduced by a generation of younger scholars, as are new extensions of the Berlin–Kay approach.

The chapters in this volume

In 1992, the National Science Foundation and Syracuse University sponsored a working conference on color categories in thought and language at the Asilomar Conference Center in California. Its purpose was to bring together both junior and senior visual scientists, anthropologists, and linguists to inform one another about the state of the art and to formulate agendas for new research. The essays in the present volume are based on talks and discussions from the Asilomar conference, revised and updated. They begin with a sneak preview of the World Color Survey and its analysis. The next section is devoted to the questions that the Berlin–Kay findings have raised for visual science, as well as the efforts that visual scientists have made to deepen our understanding of cross-linguistic color naming. In the third section linguists and anthropologists present some recent empirical and theoretical work in the Berlin–Kay tradition. The fourth section presents two dissenting views, one questioning the application of opponent-process theory to color-term research, the other challenging the Berlin–Kay research program. In the concluding chapter, the editors reflect upon some of the themes and issues in the present volume, and point out some directions for future research.

In the first essay, **Kay, Berlin, Maffi, and Merrifield** present the most recent results of the ongoing analysis of cross-linguistic data on color categorization and naming that have issued from the World Color Survey (WCS), and discuss the WCS data within the context of some new theoretical proposals concerning the classification and evolutionary trajectory of basic color-term systems. These proposals include a reconceptualization and simplification of the notion of "basic (color) stage" of a language, now understood as the developmental status of a language vis-à-vis its composite and fundamental color categories. Two distinct, although interacting, processes are proposed as providing the main mechanisms of color term evolution: the dissolution of the white/warm "channel" and the dissolution of the black/cool "channel." Based on this new conceptual framework, a more perspicuous notation for color system types is presented. Analyses of WCS languages are offered to illustrate the stages of the new evolutionary scheme.

The links between the findings of the WCS and visual science must be sought at several levels. We begin our examination of color vision at its foundations, in psychophysics, the systematic, quantitative study of human perceptual response. **Wooten and Miller** give us a brief history of psychophysical investigations into color vision that touches on the contributions of Newton, Young and Helmholtz, and finally Hering. Special attention is paid to Hering's distinction between the light–dark and black–white systems, and to the differences between both of these achromatic systems and the chromatic system. Wooten and Miller describe the Hurvich–Jameson cancellation technique for measuring the relative responses of the opponent systems, and exhibits representative measurements. The red–green system proves to be a linear fit to the appropriate photopigment responses, but the blue–yellow system is not. When people are asked to name the percentages of red, yellow, green, or blue that they see in a spot of light, they are able to do so reliably, and the color-naming data closely track the chromatic response curves obtained by the cancellation technique. Sternheim and Boynton developed a procedure that has been used to show that red, yellow, green, and blue are both necessary and sufficient to name all of the spectral hues; they are in this sense more elemental than orange, say, or purple. An extension of the procedure to simulated surface colors shows that brown is not elemental either, despite its *prima facie* dissimilarity to its parent, yellow (browns are *blackened* yellows). An anomalous outcome of the Sternheim–Boynton procedure is that for a few people, green seems not to be elemental, but a new procedure by Miller (see below) indicates that this is subject bias rather than a genuine perceptual effect. The link between the psychophysical results and the Berlin–Kay sequence seems clear for the Hering elementary colors, but not for the particular Berlin–Kay pattern for derived colors. Why, for instance, is orange basic whereas chartreuse is not?

What do we know about the neural mechanisms that underlie the perceptual phenomena that are described by psychophysics? **Abramov** first sketches the overall functional physiology of the color-vision system, leading from the cones through the lateral geniculate nucleus to the visual cortex, and tells us that much of what was previously believed about the neural basis of color requires revision. For example, it had been supposed that it is the existence of three distinct kinds of photopigment that establishes the trichromacy of human color vision, but it is now known that there is a wide variety of human photopigments, so trichromacy must be established at a later stage – the LGN cells – where cone outputs are compared. The spectral responses of the LGN cells fall into four general classes, and, according to earlier thinking, these correspond to the four unique hue sensations. Although their responses do in many ways parallel color naming in human subjects and are centrally involved in color vision, the LGN cells cannot be identified with the ultimate hue mechanisms, since they do not explain the perception of redness at the short-wave end of the spectrum. More importantly, they respond well to white light and therefore cannot disambiguate hue from luminance, and their crosspoints are widely scattered and much too labile. Nevertheless, LGN and cone responses do strongly constrain the characteristics of neural hue mechanisms, as do the psychophysical responses at the other end. Very recent models require four rather than two opponent mechanisms to yield the hue channels. Some of the possible brain sites for these mechanisms are discussed, along with the response criteria that any putative site would have to satisfy.

Rather than looking at the behavior of small groups of neurons, one can examine underlying mechanisms of color perception and categorization by studying the changes of perception and behavior that occur with brain-damaged people, and correlating these deficits with brain function. **Davidoff** asks whether our brains have distinct mechanisms for color perception, color categorization, and color naming, or whether all of these are handled by the same basic processes. He suggests that we can gain a foothold on such questions by examining disorders of color perception consequent on injury to specific areas of the brain, particularly in cases of acquired central achromatopsia. In the clearest cases of this disorder, brightness perception is good, boundaries are readily detected, thresholds indicate that retinal opponent processes are operative, but there is a total loss of the ability to discriminate hue, and patients report that they are unable to see color. What is damaged is an area in the lingual and fusiform gyri of the temporal lobe. Some patients suffering from such damage remember and imagine colors and are able to name them. However, there are patients with different conditions who are able to see colors and categorize them but cannot name them. Others see colors and remember color names but are unable to apply the names correctly or to sort objects by color. Yet others can identify the colors of objects but are otherwise unable to identify those objects. Taken together, these cases suggest a functional and modular arrangement involving a pictorial register in which colors and shapes are brought together, an internal color space which serves as a memory store, and a color-naming center. Infant studies give us some reason for supposing that the default organization of the internal color space is based upon the Hering elemental hues, but it is much less clear that opponency is hard-wired as well; this may be a function of experience and the properties of the neural inputs to central mechanisms. What other constraints the default neural organization of the internal color space might place on the formation of linguistic categories for color is at the moment unclear, though clinical cases suggest that the internal color space is unlikely to include other surface attributes such as pattern.

Boynton is interested in what psychological significance attaches to Berlin and Kay's distinction between basic and non-basic color terms. He describes a series of investigations of color categories in which he used a variation of color-naming applied to an extensive sampling of color space rather than just to spectral colors, as in the Sternheim–Boynton procedure, or just to the outer skin of the space, as with the Berlin–Kay stimulus materials. For this purpose, he used the Optical Society of America–Uniform Color Space. The OSA color space contains 424 samples that, unlike the Munsell set, are equally spaced across all three dimensions. Boynton and his collaborators asked native English (and subsequently Japanese) subjects to name each member of the randomly presented set twice, with any monolexemic names they chose to use. Responses were compared with respect to consistency, consensus among subjects, and time between presentation and first response. On all of these measures, basic color terms are clearly differentiated from non-basic terms, but there is no clear differentiation between terms for the Hering elemental colors and the derived basic colors. Weighted averages ("centroids") of color chip choices were calculated for each basic term. The centroids of chromatic terms (save brown and pink) are typically highly saturated, and for those whose memberships overlap, are never separated from one another by more than 7.5 OSA units. Red and yellow never overlap, but both frequently overlap with chips called "orange." Orange thus serves as a bridge between red and yellow, and yellow bridges orange and green. This is surprising, given the composite nature of the one and the elemental nature of the other. A large region, called "tan" or "peach," is unnamed by any basic color term. Consensus samples for red and yellow are found at relatively narrow lightness levels, whereas consensus samples for green and blue extend over virtually all lightness levels. No chromatic plane at any lightness level includes all of the basic chromatic colors. Boynton concludes, "I feel it reasonable to suppose that there may be eleven categorically separate varieties of [brain] activity, corresponding to each of eleven kinds of color sensations that are identified by the eleven basic color terms. It might be productive, I think, to consider these as the pan-human perceptual fundamentals."

By the standards of the Sternheim–Boynton computed-hue technique, for some people green is not an elemental color. To explore the suspicion that these people are "paint-biased," i.e., influenced in their performance of the task by early experience with pigment mixing, **Miller** employed a new technique in which people were asked to estimate the percentage of a *single* hue in their perception. The results of the technique agree well with applications of the Sternheim–Boynton method in other cases, and by using it one can counteract the effects of paint bias in people's responses: green is indeed elemental. In a second application of single-hue naming, a fast-response forced-choice technique shows that "chartreuse" is a redundant term, whereas "orange" is not. The first procedure distinguishes elemental from non-elemental basic hues, the second distinguishes basic from non-basic binary hues. Both techniques were designed to minimize high-level cognitive factors. The experiment with orange and chartreuse provides the beginnings of an answer to one of the questions we posed earlier: why some binaries but not others are encoded as basic color terms. As Miller concludes, "Our findings suggest that the distinctions between elemental hues, basic, and nonbasic colors are useful and measurable."

So far, two systems of ordering perceived colors, the Munsell and the OSA, have been mentioned. **Sivik** introduces us to a third, the Swedish Natural Color System (NCS), which is based on the principles of opponent-process theory. The Munsell system, widely used in the US, is based on a lightness dimension (Value), a saturation dimension (Chroma), and a Hue dimension. Its design aim was to achieve equal perceptual distance within each dimension. Munsell divided the hue circuit into five sectors of twenty steps each, the resulting principal hue divisions being purple, red, yellow, green, and blue. Subsequent adjustments to the system to improve the spacing have put Munsell 5R, 5Y, and 5G – but not 5B – close to their respective unique hue points. The NCS is scaled by estimating the degree of resemblance that a color sample bears to ideal red, yellow, green, blue, black, and white. A sample is specified by estimating its chromaticness, hue, and blackness in percentage terms, the total of the three adding to 100. There are several important differences between Munsell and NCS. NCS is based on direct estimation rather than by comparison with samples, so use of the NCS (but not the NCS atlas) is independent of lighting conditions. Munsell is open on the saturation dimension, whereas NCS is closed (thus NCS chromaticness can be estimated and Munsell Chroma cannot). Munsell space is based on just-noticeable differences between neighboring colors, NCS on degree of resemblance to elementary colors. Munsell takes lightness to be fundamental, NCS uses blackness instead, regarding lightness as a derived dimension. Which, if either, of the two systems better represents the psychological space by which people categorize colors is a matter of dispute. In any case, Berlin and Kay's selection of samples from just the "outer skin" of the Munsell solid leaves color categorization in the interior portion unexplored. Sivik then describes how he and his associates have been using the NCS atlas and semantic differential techniques to study the references of pairs of terms frequently applied to color such as "warm–cold," "weak–strong," "beautiful–ugly," "active–passive," etc. The whole color space has been sampled, and the work has been extended to cross-cultural comparisons. In later studies other connotations of colors have been studied, using a descriptive model of color combinations based on dimensions such as interval/contrast, chord/color content, and balance/tuning. Strong relationships have been shown to exist between these stimulus-describing variables and the semantic connotative dimensions.

Linguistic and anthropological work on color categorization and naming in the Berlin and Kay tradition has spanned all levels of research, from methodology to theory to specific points of analysis. The essays included in this volume present some of the most recent advances at these various levels, addressing such key issues as the concept of basicness and its measurement; basic and non-basic terms; the nature and factors of color category evolution; universality and relativity in color classification; new methods of data collection; previously unreported types of color categories and cognitive mechanisms of category formation; and the possible genetic and evolutionary underpinnings of human color classificatory behavior.

The notion of basicness is taken up by **Corbett and Davies**. Assuming Berlin and Kay's original criteria for basicness, these authors propose to test the validity of various behavioral and linguistic measures of basicness against languages such as English, Russian, Japanese, French, Hebrew, and Spanish, whose inventories of basic color terms are well established. They assess the performance of each test in predicting the basic color term inventory of each language sampled (or separating basics from non-basics); in discriminating, within basic terms, among primary basics (the Hering fundamentals) and secondary basics (the derived categories); and in revealing regularities in the ordering of the basic terms in a given language, to be compared to the Berlin and Kay evolutionary sequence. The results, while providing overall support for Berlin and Kay's theory, indicate that different measures do better at different tasks, in a way that is consistent across languages. Elicited lists of color terms perform best in distinguishing between basic and non-basic terms; they can constitute a reliable, easy-to-use field tool for data collection on basic color terms. Frequency of occurrence in a text corpus discriminates between primary and secondary basics and is the best predictor of correlation with the Berlin and Kay sequence. A complementarity between these two measures is suggested.

Issues of color-category evolution are taken up by **Casson**, in the context of the development of English color terminology. Casson's study of basic and secondary color terminology from Old English to Modern English, from the seventh century to the present, reveals patterns that are similar to those observed in other languages of the world. Old English color terminology was mostly focused on brightness (lightness as well as shininess). Even those terms that would later become the basic color terms of English originally had prevalent brightness rather than hue senses. Hue senses became prevalent in Middle English (c. 1150–1500). This shift was paralleled, in the same period, by the emergence of secondary color terms that were exclusively hue terms and were derived by metonymic extension from words for physical entities. Casson relates this shift in English color terminology to the development of dyeing and textile manufacture as one factor that tended to bring about an increased complexity of the color world and a greater need for effective communication at this level.

Questions of color category evolution are also addressed by **Stanlaw** in his study of Japanese color terminology. He examines the role of language and culture contact in promoting change in this domain, along with the possible implications of the phenomena observed for the issue of universality vs. relativity in color classification. Stanlaw focuses on two aspects of Japanese color vocabulary. The first one is the use of English loanwords for derived color categories. Both color-name listings and word-frequency counts show a high correlation for Japanese with Berlin and Kay's evolutionary sequence. However, they also show color loanwords to be more salient than their Japanese counterparts. Such loanwords appear to be replacing the corresponding Japanese terms in an order approximately inverse to that of the Berlin and Kay sequence. The second aspect of Japanese color nomenclature considered in this chapter relates to the use of the term *ao*, currently meaning "blue," but previously naming a green–blue category, to refer to the color of the green ("go") traffic light. This choice seems to be due to the specific connotations carried by *ao*. Native Japanese people residing in the US for extended periods of time tend to remember the color of the "go" light in Japan as being bluer than those who have come from Japan more recently, suggesting a mild "Whorfian effect" (influence on thought by language).

MacLaury, in his chapter, introduces the reader to the methodology and some of the results of his Mesoamerican Color Survey (MCS), and presents a theoretical framework, "vantage theory," that he has elaborated to account for his findings. A data collection procedure, partially modified from that of the WCS by the addition of a category range mapping task, reveals a peculiar pattern of color categorization in some of the Mesoamerican languages studied by MacLaury: the range of the black category encompasses that of the Cool (green–blue) category, although the term for the Cool category is amply used in color naming. This and related observations, such as that of "coextensive" ranges in the Warm category, discussed elsewhere by MacLaury, have led him to propose that color (and possibly other) categories are constructed in a way analogous to the construction of a physical point of view, with variable coordinates. According to MacLaury, the organization of a category results from the interplay of neurally grounded perception and a cognitive mechanism he refers to as "selective emphasis" on, or attendance to, similarity vs. difference. The implications of the "vantage theory" model are discussed here with special reference to the finding that first, when the focus of the Cool category in MCS languages is in blue, this focus appears to be skewed, or polarized, and second, when green and blue are categorized separately, their respective foci tend to darken, although more in blue than in green. MacLaury asserts that his model provides the active cognitive principle that propels category change, as distinctiveness gets progressively emphasized over similarity.

The body of research on cross-linguistic color categorization and naming is examined by **Zegura** from a human evolutionary perspective and in relation to recent findings on the genetics of color vision. The prevalent assumption in color classification studies has been that of an essential sameness of human color vision, presumably based on close genetic similarities. The existence of cross-linguistic universals in the domain of color has generally been traced to this assumed common biological basis. However, Zegura points to the discovery by Nathans and his associates that individuals with normal phenotypic function present greater polymorphism than was previously thought in the genes for the so-called "blue," "green," and "red" photopigments (opsins). This applies both within and across various primate species, including *Homo sapiens*. Psychophysical correlates have been suggested for this genetic polymorphism, in the form of color-matching differences in human populations. Zegura raises the question of whether such genetic differences may also underlie intra- and interpopulational differences in color term systems. Since humans display ongoing genetic evolution in the opsin system, Zegura also considers the possibility that this may provide the underlying mechanism for the continued development of basic color terminologies – perhaps correlating with a cognitive mechanism, such as that proposed by MacLaury, of shifting attendance to difference vs. similarity.

The prevailing tenor of the essays in the present volume is that the opponent-process theory of color perception is the fundamental starting-point for forging the links between color vision and color categorization. The Natural Color System is explicitly organized in accordance with the opponent scheme, and Sivik and others have for that reason urged that it be more widely used in studies of color categorization. **Jameson and D'Andrade** argue instead that opponent theory and the NCS are problematic foundations for the understanding of color categorization. They maintain that studies of the similarities that colors bear to each other generally do not yield opponent color space, but correspond more nearly to a Munsell space, with a five-hue rather than a four-hue organization. Neither additive mixture nor successive contrast yields an opponent structure, especially where red and green are concerned, but both sorts of complementation are well approximated by the oppositions in Munsell space. The electrophysiological studies of LGN cells also fail to speak unambiguously in favor of the fourfold-hue scheme of opponent theory. Furthermore, the scaling of large-scale perceptual color differences is not precise enough to determine what pairs of colors are psychologically furthest apart. Rather than appealing to the psychophysiological importance of the Hering primaries, the authors suggest that it might be fruitful to explain the Berlin–Kay evolutionary sequence in terms of those successive partitions of color space that are most informative: if one has only two color terms, the most informative system is one that would split the