

Tutorial on the Importance of Color in Language and Culture

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Abstract: This tutorial examines how people of various cultures classify different colors as belonging together under common color names. This is addressed by examining Berlin and Kay's (1969) hierarchical classification scheme. Special attention is paid to the additional five (derived) color terms (i.e., brown, purple, pink, orange, and gray) that must be added to Herings' six primaries (i.e., white, black, red, green, yellow, blue) to constitute Berlin and Kay's basic color terms. © 2001 John Wiley & Sons, Inc. *Col Res Appl*, 26, 179–192, 2001

Key words: color naming; language; culture; evolution; development

INTRODUCTION

One of the most interesting consequences of mental activity is that the continuous physical dimension of wavelength tends to be perceived as discrete hues. That is, humans group wavelengths into color categories, such as “red,” “green,” “yellow,” and “blue.” These categories are formed, in part, by linguistic and cultural factors. This can be demonstrated by examining how color naming and the perceptual grouping of colors varies across cultures. This linguistic/perceptual grouping of colors has several important philosophical implications. For example, it calls into question whether color categories can be defined via specific qualities of physical objects or whether the classification of wavelengths reflected from an object is subjectively interpreted using language as a translator. Consequently, this tutorial begins with a few definitions to help put these larger philosophical issues into context.

The overall direction of the tutorial considers the relationships among different wavelengths of light and how they generate different color names across cultures. To address these cultural differences properly, the physics that determine how wavelengths of light are made available to

the eye are considered first. A brief description follows of the medium that transposes these external events into perceptions, that is, the human biology that regulates color vision. Once the physics of external reality and the biological filter that processes those energies has been outlined, a discussion of Berlin & Kay's 1969 hypothesis¹ and supporting works are used to tie color categorization to linguistics. Since Berlin & Kay's work has received several significant criticisms, a number of counterexamples follow. What is most significant regarding Berlin & Kay's hypothesis is that as cultures develop, they acquire additional color names in systematic order. Berlin & Kay initially postulated that this was due to successive encoding of color foci, while in later work they considered it to be due to the successive partitioning of color space. One way to explore how the later might occur is to examine how children acquire color names as they develop. These arguments are considered in the tutorial's final section.

DEFINITIONS AND PHILOSOPHICAL ISSUES

Realism asserts that physical objects in the external world exist independently of what is thought about them. That is, they exist even if never perceived. The most straightforward of such theories is known as *naïve realism*. It contends that humans are made directly aware of objects and their attributes via perception and thus have immediate access to the external world. This view fails, however, to explain phenomena such as illusions, causing most realists to argue that causal processes in the mind either mediate or interpret the appearances of objects. The mind does this by creating internal representations called sense data. Thus, objects remain independent of the mind, but the mind's causal mechanism may distort, or even wholly falsify, an individual's knowledge of them. This is especially problematic in that it makes the truth-value of human perceptions uncertain. However, if it were possible to use reason to determine how the causal mechanisms relate to a final percept, it would be possible to extrapolate what actually exists in the physical world. This makes understanding the relationship

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between the mind's use of language and color classification particularly appealing.

Naïve Realism in its purest form, however, states that colors as we perceive them exist in the external world independent of mind and language. For example, John Lyons' famous work on *Color in Language*² states that

“Color is the property of physical entities and substances that can be described in terms of hue, luminosity (or brightness) and saturation that make it possible for human beings to differentiate between otherwise perceptually identical entities and substances, and more especially between entities and substances that are perceptually identical in respect of size, shape and texture” (pg. 198).

Therefore, when someone asks to be given “the blue book” vs. “the green book,” it is possible to differentiate between the two books based on color alone. The language of color naming, in this case, is merely a descriptive device. It denotes a fact about a specific aspect of physical reality. But what if someone from a particular culture says both books are “glas,” as the Welsh would do? That is, they ask to be given “the glas book.” Because the Welsh use the word “glas” to include both blues and greens, it would be impossible to know which book to give them. This suggests that because the Welsh do not have different words for “blue” and “green” they do not segment the different color categories of “blue” and “green,” and thereby may not *perceive* them as distinct entities.

This notion is exactly what a group of theorists called Relativists claim. *Relativism* proposes that what is perceived to exist in the external world is always a matter of perspective. The famous ancient Greek Sophist thinker Protagoras put it best when he claimed that “man is the measure of all things.” This implies that Relativists believe that color terms cannot always be brought into one-to-one correspondence across languages. They believe that color categories are relative, and that how colors are named affects how they are perceived. Relativists most often follow the *Sapir-Whorf hypothesis*,³ which suggests that each language imposes on an individual's kaleidoscopic flux of impressions its own idiosyncratic semantic structure. It is from these linguistic categories that color categories are derived. Interestingly, Relativists have collected many cultural examples of this type of phenomenon. For example, in Russia there is no single word for “purple” as there is in English. But there are two separate words for blue. “Goluboi” for what Americans would call light blue, and “sinji” for what Americans would call dark blue. Thus, the Sapir-Whorf hypothesis emphasizes that semantic structure is relative while it minimizes the role of linguistic universals.

Universalism, on the other hand, refers to stable universal truths. Thus, color categories would have an inherent and essential quality that does not depend on the perceptions of human viewers. Universalists claim that all grammatical and lexical structures of languages are isomorphic, that is, interchangeable. While most Universalists would agree with

the Relativist's anecdotal data that color names and color categories differ across cultures on the surface, what Chomsky⁴ would call “surface structure,” they insist that the color names denoting color categories share a common “deep structure” that cuts across languages and cultures. This notion of preselected categories harkens back to Immanuel Kant's⁵ conception of a nativistic mind.

Relativists challenge this position by asking how one can be certain if how they categorize a color represents what exists in the external world. There may have been a distortion at some point in the transfer process from the objective external world to the subjective mental world of humans. A stronger version of this paradox is that it is never possible to occupy a viewpoint other than one's own. That is, if two or more individuals are looking at the same objects, they perceive the same colors. What the observers share collectively is a language specifying that they give their common color percepts a common color name. This, however, may not happen and different cultures may categorize the same perceived colors differently. For example, one group of individuals may incorporate into their language that two given pieces of sense data should be called *X* and *Y*, respectively, and a second culture stipulates that the same sense data be divided differently and called *Q* and *R*, respectively. This allows the possibility that *Q* contain all of *X* and some of *Y*, while *R* contains the remainder of *Y*.

What is important to realize is that these linguistic differences and the categorical segmenting of color space may be lawfully governed. The main idea put forth in this tutorial is that the perception of color categories evolves in parallel with the language of color naming. This is demonstrated by focusing on the Universal hierarchical classification scheme of color naming first put forth by Berlin and Kay¹ in 1969, which has since been modified by Kay and McDaniel⁶ in 1978 and MacLaury⁷ in 1992.

PHYSICS: LIGHTS VS. SURFACES

Some of above philosophical conundrums result from the unique role of vision as a sensory system. In touch, for example, the skin's pressure receptors are directly stimulated by external surfaces. This makes it easier to accept, perhaps erroneously, that naïve realism is correct. That is, what one perceives is what actually exists in the external world. In vision, however, the colors that humans perceive as part of external objects do not directly abutt the sense organ of the eye. Rather, color information is received as various wavelengths of light impinging upon the retina. This light is the physical product of having a particular source of illumination strike an object, which reflects some of those wavelengths back toward the observer's eye. This makes the study of color naming vs. color perception particularly interesting. What is named is a color category of a quality thought to be a property of an external object.

As mentioned above, however, Russians call the American light blue “goluboi,” and the American dark blue “sinji.” Thus, color names and color categories often include whether the colors that are perceived and thereby

classified are light or dark. Light and dark, however, are qualities of a surface that is colored, not a property of lights, *per se*. Physical light is neither light nor dark, it is merely more or less intense. Consequently, when wavelengths of light between 350–700 nm affect the eye, what is named, and possibly perceived, is the color of a surface external to the eye.

BIOLOGY: OPPONENT PROCESSES AND COLOR PERCEPTION

Three types of cone photoreceptors form the basis of the *trichromatic theory* of color vision. The incoming wavelengths of light are captured by (a) short wavelength cones (S), (b) middle wavelength cones (M), and (c) long wavelength cones (L); having their peak sensitivities at 419, 531, and 559 nm, respectively. Trichromacy accounts for the perception of individual wavelengths within the spectrum. How the wavelengths are grouped perceptually into color categories requires understanding the subsequent neural processes of color opponency that occur in the retina and further along the visual system.

Opponent process theory provides an explanation of color contrast, or how the colors of surfaces are perceived relative to surrounding surfaces. For example, it explains how a yellow patch on a green background appears more reddish than it does on a gray background. Likewise, on a blue background the same yellow patch appears more saturated, while on a yellow background it appears more desaturated. Thus, triplets of cone responses are insufficient to specify uniquely the colors we perceive. *Simultaneous color contrast* demonstrates that the colors we perceive as belonging to a given surface depend not only on the cone responses activated by that surface, but also on surrounding cone response triplets as well.

Because the cone responses overlap considerably throughout the spectrum, their responses are highly correlated. This has led Peter Lennie⁸ to postulate that, for a color detector to distinguish how much each of the three cone types is activated by an object, the cone responses must be decorrelated. This is achieved by neurons that, in effect, pit the cone responses against each other in an antagonistic or opponent fashion by responding to differences in the various cone absorption spectra. “On” and “off” ganglion cells in the retina perform this function by using a center-surround organization to define the cell’s *receptive-field*. “On” cells are excited by any light present in the middle of their receptive field, but are inhibited by an annulus immediately surrounding this central area. This situation is reversed for “off” center cells. These two types of cells overlap the same retinal area and by operating in parallel form a spatially antagonistic push-pull system responding to increments and decrements of light.

Spectral antagonism requires certain neurons be excited by one cone type and inhibited by another. This is how ganglion cells (as well as other types of neurons further along the visual pathway) can enhance the difference between various cone absorption spectra while discounting redundancies in the highly correlated cone signals. A simple

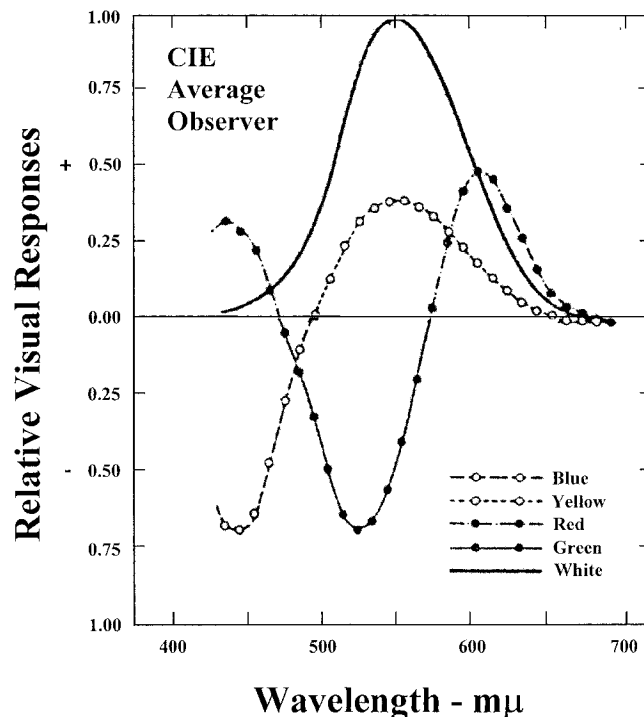


FIG. 1. Theoretical chromatic (red-green and yellow-blue) and achromatic (white) response function for equal energy spectrum for CIE average observer. It shows the level of activation of the three opponent processes at each wavelength. (Reprinted with permission from ref. 9, Fig. 6.)

model of color opponent processes, sufficient for our discussion, has three post-receptor channels. One is the achromatic $L + M$ channel. Because this channel is additive and not spectrally opponent, it signals differences only in luminance, not wavelength. A second channel, the $L - M$ channel, pits the long and middle wavelength cones against each, thus providing chromatic information along the red-green dimension. The last channel is also chromatic, and is composed of $S - (L + M)$ signals, thus regulating the blue-yellow dimension.

Figure 1, taken from the CIE average observer,⁹ represents the three visual response curves that such a model would generate. The achromatic (solid) curve is sometimes considered the “whiteness” response, because it is always positive. Being positive is the reason that black can be produced only by antagonistic spatial contrast. The other two chromatic curves cross the zero point in several locations. At these points the chromatic channel is nulled. For example, this occurs when the red-green response curve (closed circles) crosses zero at 495 nm. This indicates that lights at these wavelengths are neither red nor green. However, the yellow-blue response curve (open circles) is negative at this point, indicating that the light is activating the chromatic blue side of the opponent process. Thus, this wavelength is called unique blue. That is, it is neither red, nor green, nor yellow.

At 500 nm unique green is perceived. This is because the blue-yellow channel (open circles) is nulled (i.e., set to zero) at this wavelength, while the red-green channel signals a negative response indicating that only the green response is

active. At 577 nm unique yellow is perceived as the red-green channel (closed circles) is nulled, while the yellow-blue channel signals a positive response to yellow only. Interestingly, to generate a unique red requires adding some short wavelength light. This is because the longer wavelength (i.e., red channel) response range always includes some amount of yellow. This must be nulled by adding some blue from the yellow-blue channel. To desaturate any of the above-mentioned chromatic responses simply requires adding signals from the additive achromatic “white” channel.

When the chromatic response curves cross each other, balanced, binary composites of light are perceived. For example, at 495 nm the green and blue responses cross, producing the perception of blue-green; which some individuals label as turquoise. This happens again around 590 nm, where the red and yellow response curves cross, producing the perception of a yellow-red binary that many call orange.

The response curves of Fig. 1 suggest that, while specific wavelengths of light provide the proximal stimuli for color vision, these lights do not in any straightforward way determine color categories. As will become apparent, however, the six primaries that these opponent process response curves generate (white, black, red, green, yellow, and blue) go a long way in explaining how color categories are formed.

BERLIN & KAY HYPOTHESIS AND SUPPORT

The central premise of this tutorial is that cultures drive language, and language drives the perception of color categories. However, the role of biological processes, especially the color-opponent processes (first conceived by Hering¹⁰) outlined above, are also relevant. Hence, we establish parallels between biological processes and linguistics by dividing Berlin & Kay’s¹ findings into two components. Part one deals with Berlin & Kay’s first six color terms. They are black, white, red, green, yellow, and blue; and correspond closely to Herings’ six primaries. Part two focuses on the additional five color terms that constitute Berlin & Kay’s eleven basic color term’s classification scheme (Fig. 2). Speculation is provided as to why brown, purple, pink, orange, and gray are late-developing color categories. At this point, it is also interesting to consider what the evolutionary history of languages might predict will be the next color category. We also speculate as to why “chartreuse” (i.e., a green-yellow binary) may be eliminated as a possible contender, even though “orange” (i.e., a yellow-red binary) is a basic color name. This leaves tan to become the twelfth, and newest, color category.

Berlin & Kay¹ wanted to determine if there is a basic subset of color names that people would universally agree represent the same regions of color space. Such a set would support the Universalist’s claim that color names have a one-to-one correspondence across languages, and that all cultures have the same perceptual categorization of color

Hering’s Primaries Additional Colors

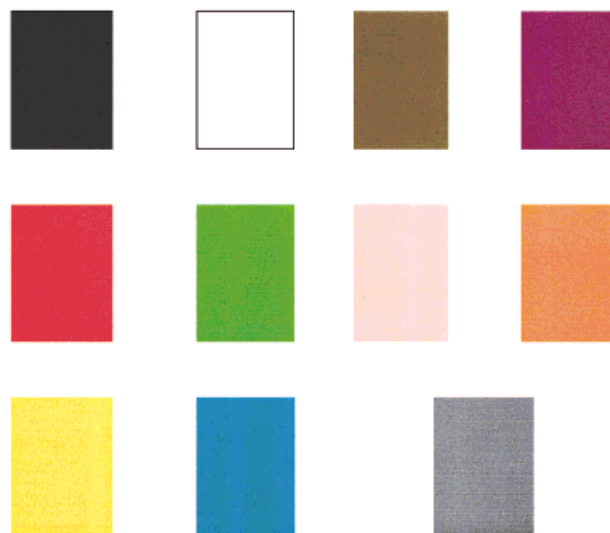


FIG. 2. Berlin & Kay’s eleven basic color terms; arranged by Hering’s six primaries (opponent processes) and five additional late developing color categories.

space. Toward that end, they first had to decide what would constitute a basic color term.

They did this by splitting basic color terms into *Level I* and *Level II* terms. A Level I term must have four main properties. First, it must be general, it must apply to diverse classes of objects. This means that its meaning cannot be subsumed under the meaning of another term. For example, crimson and vermilion cannot be considered as Level I terms, because both are included as kinds of red. Second, it must be salient. This means that it is readily elicited and used consistently by individuals with a high degree of consensus within a given culture. Third, it must be lexically simple, meaning it cannot be a composite, like reddish or brown-red. Lastly, it cannot be context-restrictive, like “blonde.”

Using these four criteria, Berlin & Kay determined that English speakers have eleven basic color terms that correspond to eleven distinctly separate color categories (Fig. 3). The achromatic colors are black, white, and gray. The six chromatic colors, also known as Newton’s prismatic colors are red, orange, yellow, green, blue, and purple. Berlin & Kay’s use of the color name “purple” takes the place of Newton’s two related color categories, indigo and violet. Lastly, there are the nonprismatic colors, which are basically variations in luminosity and saturation, such as brown and pink. These eleven colors constitute Berlin & Kay’s Level I terms. Level II terms are all the color terms that do not meet the criteria for Level I terms, but can be defined by Level I terms. For example, scarlet is really a brilliant red with a tinge of orange, mauve is a pale purple, turquoise is a blue-green, and beige is a yellowish gray.

It is impressive to realize that the number of English color terms can be collapsed into eleven terms, because Eco¹¹ has shown that there are over 3,000 English color words in common use! Likewise, French has over 200 color words

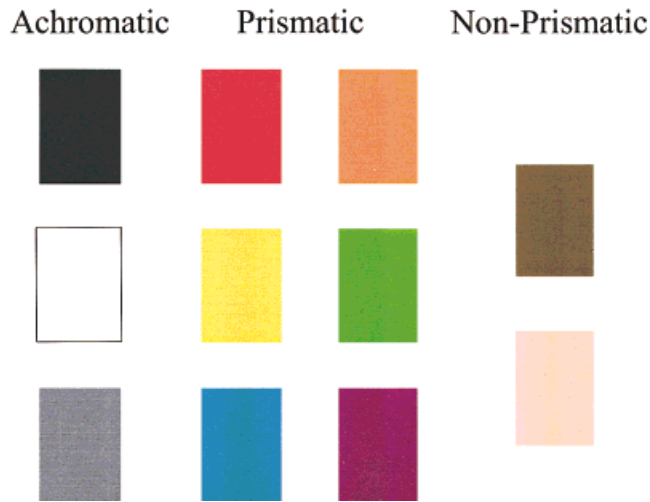


FIG. 3. Berlin & Kay's eleven basic color terms; arranged by three achromatic colors, Newton's six prismatic colors, and two nonprismatic colors.

that can be collapsed into the same basic eleven Level I colors. However, the French word "pourpe" is only equivalent to a royal purple and does not cover the violet range. Interestingly, "brun" is equivalent to brown when speaking abstractly about colors, for example "that color is brown." However, it is not equivalent to brown when referring to the attribute of a real object, in which case the word "marron" (originally meaning chestnut) is becoming more popular. For example, "my shoes are marron." The issue of speaking abstractly about color names vs. using color names to refer to specific objects is revisited when the Bellona culture is discussed below.

So, even while the maximum number of basic color names currently available in any given culture is eleven, these eleven categories do have some differences. More interestingly, however, is that less technologically developed cultures often have fewer basic color names, and as cultures evolve they seem to add additional color-terms to their vocabulary. It is this phenomenon that led Berlin & Kay¹ to consider that color naming evolves along a hierarchical classification scheme.

After directly examining native speakers of 20 languages and examining another 78 languages through literature searches, Berlin & Kay¹ found that each language had up to eleven basic color terms. However, if they had less than eleven color names, the names were not random. Instead, the evolutionary sequence was determined by the successive encoding of color foci. For example, if a given language had only two color terms (like the Papuan Dani culture), these colors would be limited to white and black. If a language had three color terms they would always include white and black and then red. Blue or green would never be the third color, for example. And if a language had five color terms they would be white, black, red, yellow, and green. Thus, the sequence that colors names take are: white, black, red, green followed by yellow, or yellow followed by green, then blue, followed by brown, and then purple, pink, orange and gray, in any order (Table I). So while 11 basic color

terms can be sequenced in 2,048 possible ways (that is 2^{11}), Berlin & Kay's Hypothesis restricts this number to 33!

To test their theory of color naming, Berlin & Kay¹ used a rectangular array of Munsell color chips of maximum available chroma (Fig. 4). These chips were vertically ordered in ten equal lightness steps and horizontally ordered by hue, with each column differing from its neighbor by 2.5 hue steps. This produces what is essentially a Mercator projection of the outer skin of a Munsell solid. They then covered the plate with transparent acetate and asked subjects from 20 different languages to mark the array with grease paint in two ways. First, they asked them to mark the best example, or focal color, of each color category. Next, they asked them to circle the region of chips that could be called by that specific color term.

Figure 5 is a typical example of how a subject from an English-speaking culture categorized Berlin & Kay's color space. The bold crosses refer to the subject's focal color, or best example, of that color name, while the differences in shading group different color categories. Notice that this subject generated eleven basic color categories of various sizes. So that while the range of colors classified as "green" is quite large, the range of colors classified as "yellow" is quite limited. Also notice that a focal color does not necessarily center itself within its color boundaries. For example, it does for "green," but not for "blue."

When Berlin & Kay¹ looked at different cultures, they noticed that each culture produced very different classification schemes for the same Munsell color array (Fig. 6). For example, someone from the Tzeltal culture of Mexico used only five categories to classify the Munsell color array and the boundaries are much different than for the English-speaking subject. However, by the time Berlin & Kay collected data from someone from the Agta culture of the Philippines, they had relinquished their original theoretical framework. After considering Eleanor Rosch's work with the Dani, they postulated that categories within color space were successively partitioned as cultures evolved. Thus, the Agta happen to show only three color categories and the boundaries are even more dispersed.

This dataset might lead one to conclude that each culture has a different color-naming strategy and there are different ways to classify Munsell space. Figures 5 and 6 seem to support the Relativists interpretation of diversity of color naming and color categorization across cultures. However, by disregarding the color boundaries and looking at a plot of all twenty cultures' focal colors, the following pattern emerges (Fig. 7). In Fig. 7, each dot represents a different

TABLE I. Berlin & Kay's evolutionary color-naming sequence.

White	Green	Purple
		Pink
	< Red	< Blue
Black	Yellow	Orange
		Gray

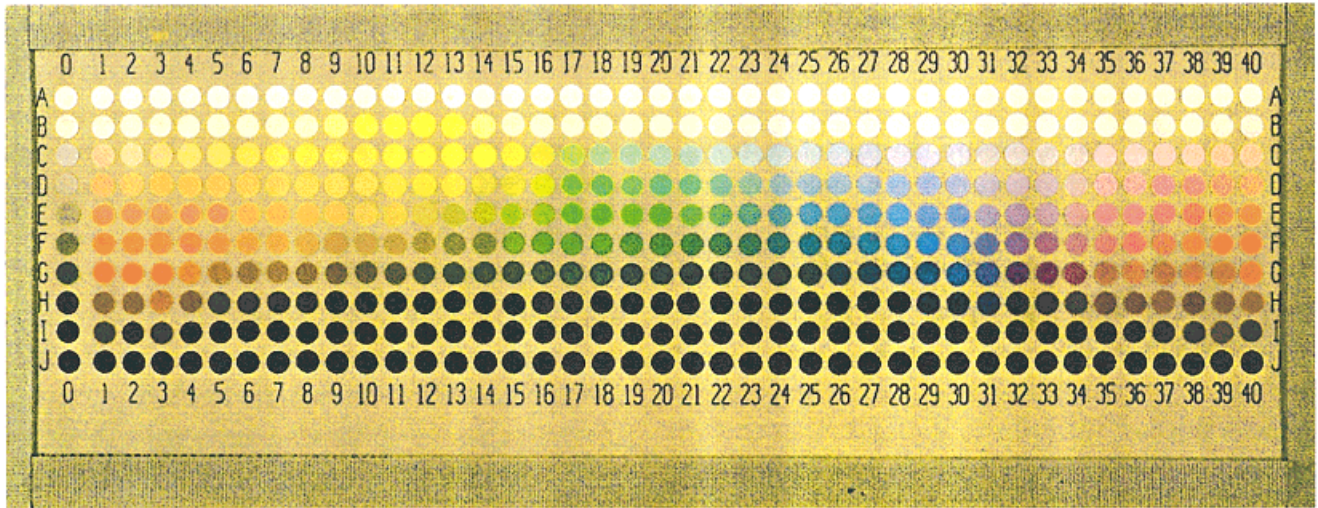


FIG. 4. Berlin & Kay's rectangular array of Munsell color chips of maximum saturation. This array was covered with asectate on which subjects marked focal colors and circled each color category. (Reprinted with permission from C. L. Hardin, 1998, *Basic color terms and basic color categories*. Color Vision: Perspectives from Different Disciplines Editors: W. G. K. Backhaus, R. Kliegl, and J. S. Werner, Walter de Gruyter, Berlin, New York, Fig. 11.1a.)

culture's focal color for a particular color name, if that culture has a color name for that particular category. For example, nineteen cultures have a color name and category for the term "green," while only fifteen cultures have a color name and category for the term "brown." This suggests that, while a given color category may not be represented at all by a particular culture, if it is represented, the best example of that color is in relatively close proximity to the same color name of other cultures that use the same term. Thus, these findings actually support the Universalist's claim.

KAY & MCDANIEL EARLY STAGES

Berlin & Kay's¹ thesis goes further and suggests that besides the clustering of focal colors there is an evolutionary, phylogenetic order in which cultures acquire new color terms. Kay & McDaniel⁶ develop this concept by demonstrating that specific languages go through particular stages in sequence to add new color terms.

Figure 8 is a schematic representation of the color-naming categorization stages various cultures go through. Berlin & Kay's¹ Stage I languages had only two categories, in essence black and white, with pure white and pure black as their focal colors. However, this presented a theoretical equivocation when, by advancing to the Stage II, the color term "red" would require that the extensions and boundaries of white and black be retracted to make room for the new "red" category. Consequently, in Berlin & Kay's model, black and white had one definition in Stage I, but referred to something else in Stage II. Primarily for this reason, Kay & McDaniel⁶ developed a *nondiscrete* formulation of *fuzzy set theory* to provide a unitary mechanism for describing the relationship between color-category foci, their extensions, and their boundaries. Berlin & Kay's¹ original formulation was a *discrete feature theory*, where the focal colors of each category become encoded in the history of a given language in a partially fixed order. Thus, "red" is always encoded before "yellow" or "green." Kay & McDaniel's⁶ reformu-

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FIG. 5. An English-speaking subjects categorization of Berlin & Kay's color space. The bold crosses refer to the subject's focal color, while differences in shading group different color categories. (Reprinted with permission from R. E. MacLaury, 1992, *From brightness to hue*, Fig. 2, *Curr Anthro* 33:137-186, University of Chicago Press.)

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FIG. 6. (Top) a subject from the Tzeltal culture of Mexico's categorization of Berlin & Kay's color space; (Bottom) a subject from the Agta culture of the Philippines' categorization of Berlin & Kay's color space. (Reprinted with permission from R. E. MacLaury, 1992, *From brightness to hue*, Fig. 2, *Curr Anthro* 33:137-186, University of Chicago Press.)

lation used fuzzy set theory to take into account that color categories are continuous, not discrete.

This can be visualized by comparing the theoretical Stage I theory hypothesized by Berlin and Kay¹ against an actual "White/Black" color system reported by Heider¹² (Fig. 9). The Dani, mentioned earlier, are the only known culture having a Stage I language. They use the term "mola" to mean a combination of "warm and light" and "mili" to mean a combination of "dark and cool." Stage II languages have three categories (Fig. 8, II). These are "whites" (stippled region) and "darks" (black region), which in Stage I of Kay & McDaniel⁶ include blacks/greens/ and blues, or "cool" colors; and reds and yellows (horizontal stripes), also known as "warm" colors. In essence, the term "mola" included the perception of warm hues with whites. This allowed the Stage II languages to separate the warm hues from the whites. While this reduced the extension of Stage I white, the new boundaries are in accordance with what was already a perceptually distinct region (see Fig. 9).

At this point, the reader may be having difficulty understanding what it means to have only three basic colors in a given language vocabulary. Harold Conklin's¹³ and Kuschel & Monberg's¹⁴ studies of the Polynesian Bellona Island

typifies what happens in such cultures. The Bellonaian's use only three color names. "Susungu" for white or light; "ungi" for black or dark; and "unga" for red. All the other colors that they refer to are contextualized color terms. That is, they are so closely connected to specific objects or emotions that they can hardly be claimed to constitute a separate color category. For example, an angry person looks "tetenga" (i.e., flushed red), while the color of one's teeth when chewing betel, a local plant, is "togho" (again a reddish color). Likewise, discoloration due to an undesired process such as rotting is denoted "seseng," while "kehu" is a reddish coconut, and "kunga" are the red feathers of a particular bird. Thus, most color names are object or state specific.

Figure 8 shows that Stage II can be followed by one of two versions of Stage III languages making four categories. Either Stage IIIa, which retains both the white and the red-yellow "warm" color divisions, and parses off darks from the blue-greens or "cooler" colors; or Stage IIIb, which retains the white and the dark "cool" colors and splits the "warm" colors into yellows and reds. If a culture is in Stage IIIa and is going to add another color term, it transitions to Stage IV by dividing the "warm" colors into red and yellow. Likewise, if a culture is in Stage IIIb and is going to add

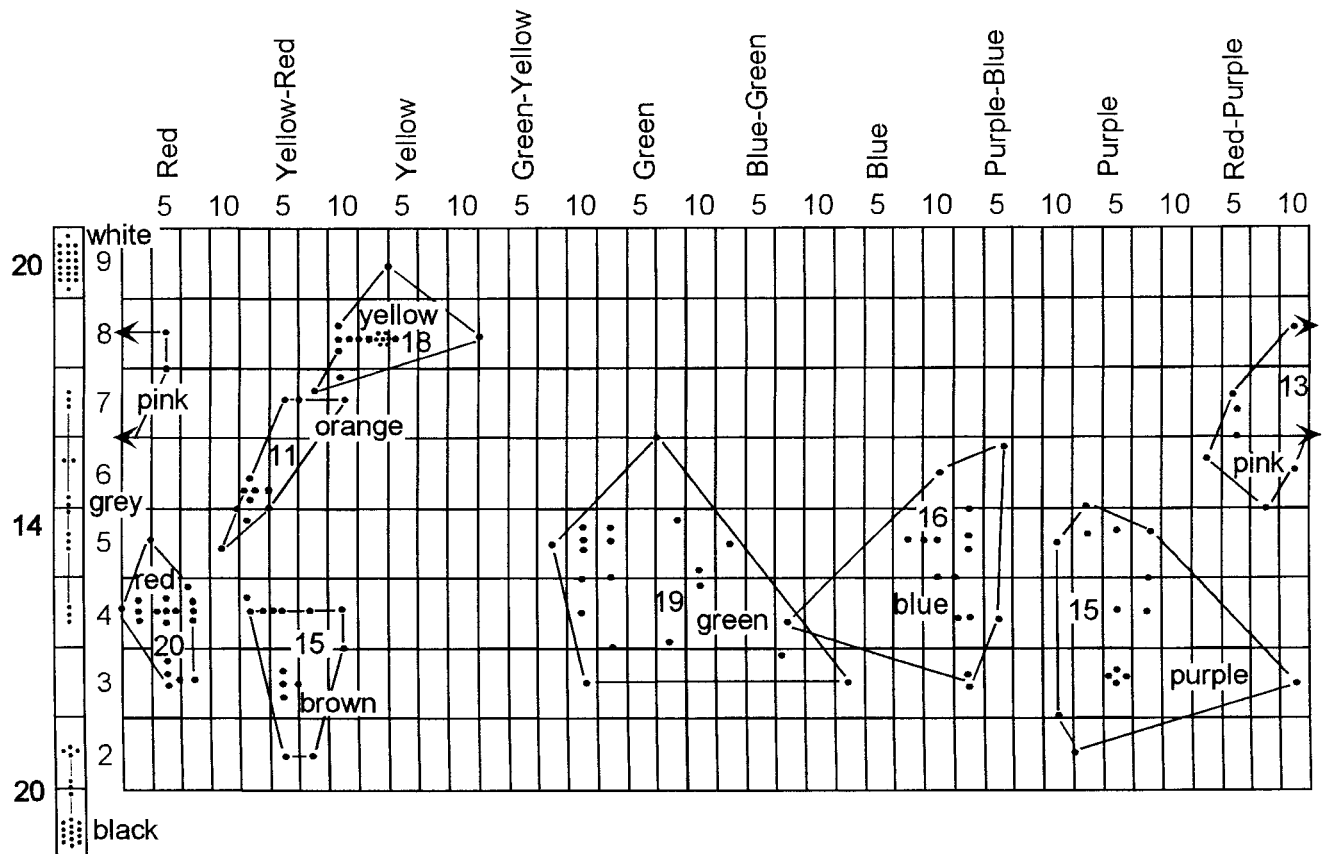


FIG. 7. Berlin & Kay's twenty cultures focal colors. Each dot represents a different culture's focal color for a particular color name, if that culture has a color name for that particular category. The best example of each color category is in relatively close proximity to the same color name of other cultures that use the same term. (Reprinted with permission from R. E. MacLaury, 1992, From brightness to hue, Fig. 1, *Curr Anthro* 33:137-186, University of Chicago Press.)

another color term, since it has already split the “warm” colors, it will parse out the darks from the “cool” colors. What is interesting is that in either case by Stage IV “warm” colors always split before “cool” colors. In many languages this blue-green mixture is often called “grue.” This derived term made up by English-speaking authors is meant to represent a combination of gr(reen) and (bl)ue. It is similar to the Welsh color name “glas” referred to earlier.

Stage V then splits “grue” into blue and green thus creating six categories; white, black, red, yellow, green, and blue. The early emergence across cultures of white, black, red, yellow, green, and blue makes Hering's¹⁰ biologically based opponent-processing the most likely force driving the evolution of color-naming. So after completing Kay & McDaniel's⁶ evolutionary stages, opponent processes are discussed in the context of human development.

KAY & MCDANIEL LATE STAGES

It is important to remember that cultures can have up to eleven categories, while there are only six Hering primaries. Thus, after blue is parsed from green in Stage V, brown is categorized in Stage VI (Fig. 8). In Stage VII, purple, pink, orange, and gray can all appear although in no particular order. These colors are relative late-comers in the basic color-naming vocabulary, and as such have several very

interesting properties. For example, Corbett & Morgan¹⁵ and Morgan & Corbet¹⁶ did a fine job showing just how ambiguous the terms for purple can be in some cultures. They reviewed several Russian dictionaries and found that the Russian names for purple and their color-space locations are not stable, yet they are for English speakers (Table II). Thus, “fioletovj” is probably the strongest contender for purple, yet each of the names in Table II can be used interchangeably. It may be that Russians cannot settle on a single color term, because purple is lowest in Berlin & Kay's¹ classification hierarchy, a relative late-comer.

Moreover, purple is composed of the intersection of red and blue, and Russian's split blue into two categories: “goluboi” for light blue and “sinji” for dark blue. Thus, it may be that lightness, a surface property, makes classifying purple for Russians particularly problematic.

COUNTER EXAMPLES

While in English “purple” is considered a basic color name, it is also a derived category. That is, it is composed of a mixture of red and blue. This is also true of the color “orange,” being a mixture of red and yellow. What is interesting, then, is that purple and orange have risen to basic color-naming status, and, therefore, complicated the notion that basic color names are the result of complementary opponent-processes. Yet, certain

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FIG. 8. Kay & McDaniel's schematic representation of the evolution of stages (seven in total are possible), which specific cultures go through to add new color terms. (Reprinted with permission from R. E. MacLaury, 1992, From brightness to hue, Fig. 1, *Curr Anthro* 33:137–186, University of Chicago Press.)

color terms have not become basic; like “chartreuse” or “lime” to denote the yellow-green binary, or “turquoise” or “aqua” to denote the blue-green binary. Whether chartreuse and turquoise might also eventually evolve into basic color names is discussed below.

Several additional pieces of evidence suggest that more than biological determinism establishes color names. First, as mentioned above, Berlin & Kay's¹ original formulation of a Stage I “White-Black” culture has never been found. Instead, the Dani group light with “warm” colors, while dark is grouped with “cool” colors in an uneven distribution across Munsell color space (Fig. 9). Secondly, the Stage III hierarchy does not necessarily follow the progression of opponent processes. That is, while white and black occur together, green does not necessarily follow red. That is, yellow might be followed by green, or *visa versa* (Table I).

More important, certain basic color names, like “orange,” may not be considered one of Herings elementary colors. For example, to establish the uniqueness of perceived hues, Sternheim & Boynton¹⁷ used a continuous judgmental technique. This entailed having subjects describe the long wavelength portion (i.e., 530–620 nm in 10-nm steps) of the

spectrum using a limited number of color response categories on a given day. On day one they allowed red, green, and blue only. On day two they allowed red, yellow, and green only, while on day three they allowed red, orange, and green only. On the final (4th) day, red, orange, yellow, and green were allowed. To prevent order effects, days two and three were counterbalanced across subjects. Subjects were flashed each wavelength and asked to consider the total amount of color in the sensation, including white, as being represented by a value of 100% (Fig. 10). That is, a 580 nm test light could be described on day two as 20% yellow, 60% red; while on day three it could be described as 80% orange, 20% red. Notice that on day two the sum of the hues was only 80%, which was permissible, because the color categories were restricted.

Three criterion were used to determine if a given hue was unique: (1) the color category was highly reliable; (2) the color function reached a maximum in a region where neighboring hues were at a minimum; and (3) the unique hue associated with a particular spectral region was not represented in a session where the color category associated with it had been eliminated. In such a session, a missing color

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FIG. 9. (Top) Berlin & Kay's original theoretical formulation of a Stage I "White-Black" culture compared to the (bottom) Dani culture's uneven distribution across Munsell color space. (Reprinted with permission from P. Kay (1975) Synchronic variable and diachronic change in basic color terms. *Language in Society*, 4:257-270. Figure is on page 259.)

function was computed. For example, on day one when only blue, green, and red were the allowed color response categories, subjects matched the entire spectrum with some percentage of green or red. A computed function for the prohibited category between green and red was obtained by subtracting the sum of the ratings for each wavelength from day four's session, where all categories were available. On day two when the allowed color response categories were green, *yellow*, and red, the yellow category function was similar in shape to the previous day's computed function.

Although the color name associated with a perceived hue could be prohibited in a particular session, a color function could be computed if that hue was unique. It was not possible otherwise, because a complex hue would be analyzed into more fundamental components. That is, when the yellow and orange categories were prohibited on day one, and the yellow category was prohibited on day three, the computed function from those days assumed the same characteristics as the yellow function did in sessions where it was allowed. This made yellow a unique hue (like green and red). However, in day two when the orange category was prohibited, the hue called "orange" in later sessions was almost completely analyzed into neighboring hues. Thus, while Kay and McDaniel⁶ consider orange a basic color name because it parses the yellow and red categories along a perceptually distinct boundary, this boundary is not defined as elementary.

Likewise, in a color naming task, Beare & Siegel¹⁸ allowed subjects to use the color names "yellow" and "red," but forbid them to use the term "orange." They showed that the spectral range around 590 nm could be fully described by yellow or red as Sternheim & Boynton¹⁷ had previously shown. However, if the term "orange" was permitted, yellow and red became constricted around 590 nm. This is especially noteworthy because of a subsequent study done by Miller.¹⁹ Miller allowed subjects to use blue, green, yellow, orange, red, and chartreuse (where chartreuse was defined as greenish-yellow or yellowish-green). He then had subjects view lights from 430-660 nm and respond by pressing a button to designate whether a particular color-name was present or absent. As expected, he found that orange restricted the ranges of red and yellow; whereas chartreuse was redundant. That is, yellow and green behaved in the presence of chartreuse much the same way that red and yellow behave in the absence of orange.

One question is whether a new color category may be on the horizon. Using the basic set of 424 chips obtained from OSA color space, Boynton & Olson²⁰ had subjects perform a color-naming task that reiterates much of what has already been discussed about color naming for English speakers. Six subjects used the eleven basic color terms originally defined by Berlin & Kay¹ while six other subjects used any monolexemic color term, meaning that compound terms such as "blue-green" and modifiers such as "dark" or "yellowish" were not allowed. The basic color names used by the first six subjects were used 88% of the time by the second group of subjects. This meant that there were regions of color space that were never given a consistent color name. The resulting nonbasic Level II color terms used at least six times by one or more subjects were tan, peach, olive, lavender, violet, lime, salmon, indigo, cyan, cream, magenta, turquoise, chartreuse, rust, and maroon.

Figure 11 plots the eleven basic color categories by lightness category. Circles of different circumference suggest different lightness levels. Filled circles of a size appropriate to their lightness level represent focal colors, which are defined as those samples that exhibit the shortest response times within their category. The centroid for each color term (i.e., the arithmetic average location) is represented as the small filled squares. Notice that some color terms are used more than others and that the focal color of a given color term is never its centroid. Likewise the area

TABLE II. Corbett & Morgan's review of several Russian dictionaries for the word "purple." Each term is equally likely to be used.

Dictionary of Spoken Russian (1958)	Muller (1965)	Gal'perin (1977)	Wilson (1982)	Falla (1984)
Lilovyj	Fioletovyj	Fioletovyj Lilovyj	Fioletovyj Lilovyj	Fioletovyj Lilovyj
	Bagrovjy Purpurnyj	Bagrovjy Purpurnyj Purpurnyj		Bagrovjy Purpurnyj

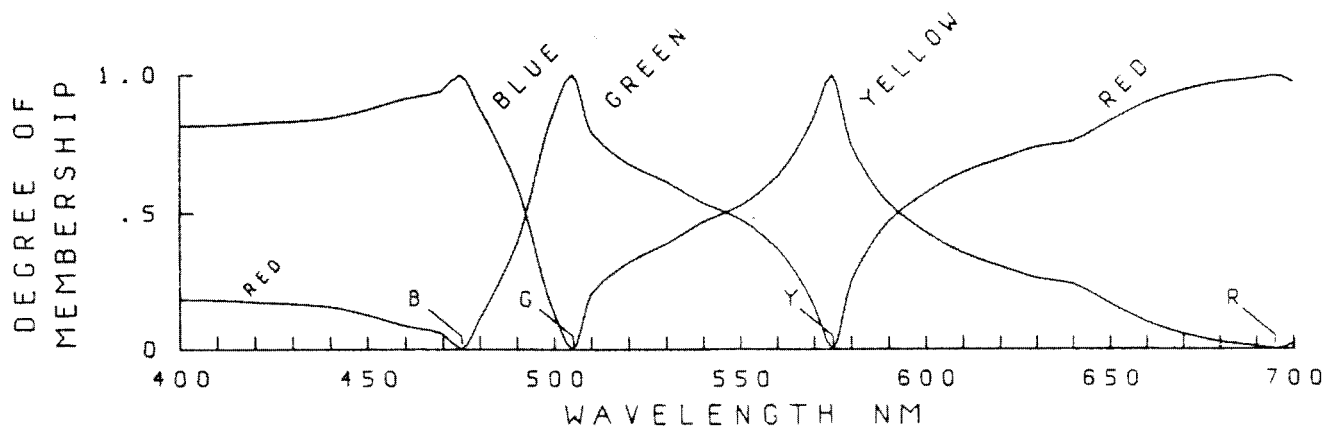


FIG. 10. Kay & McDaniel's description of the spectrum using only opponent terms⁶. Notice that orange can be broken down into combinations of yellow and red. (Reprinted with permission from Paul Kay and Chad K. McDaniel, 1978, The linguistic significance of the meaning of basic color terms, Fig. 6, *Language* 54:610–646, Linguistic Society of America.)

each color name encompasses is very uneven. For example, the circles of different circumferences indicate that blues and greens are found at all lightness levels, while reds and yellows are not. This may be because light reds are considered pink, and dark yellows are considered brown; but a similar division of the blue-green “cool” colors is not evident in English. Remember, however, that Russians *do* split their blues.

When attempts were made to use basic color terms to describe samples between the centroids of the basic color, naming became slow and inconsistent. For example, in the space between blue and green, which appears as a blend of the two, samples are sometimes called “green” and at other times “blue.” This inconsistency reveals an attempt to include components of the sensations described by the two endpoints. When this happened frequently for a majority of subjects, Boynton & Olson²⁰ said these colors were *linked*. For example, green links with both blue and yellow. However, red links with neither blue nor yellow. Because there is no sensory continuum linking certain centroids, a *bridge* is needed. Between red and yellow, this bridge is orange, and between red and blue this link is purple. What is also evident given an OSA color space is that there is a large region of color space in which there is no single color name. Some of these Level II names are peach, tan, or salmon. Boynton & Olson²⁰ suggest that this open region will be next to develop a basic color name.

ACQUISITION BY ENGLISH-SPEAKING CHILDREN

The ability to differentiate the spectrum by opponent processes supports the claim that color categorization occurs prior to, and is really independent of, language development. For example, Sandell, Gross, and Bornstein²¹ were able to train Macaque monkeys to respond differentially to colored papers. They found that response rates changed markedly as stimuli crossed red, yellow, green, and blue color boundaries. Thus, one interesting question is whether ontogeny recapitulates phylogeny. That is, can the development of color naming in children reflect how color categories have evolved with cultures?

In a preferential looking task, Bornstein, Kessen & Weiskopf²² showed prelingual four-month-old infants colored lights separated by 30 nm. The infant spectral color categories matched those generated by adult color-naming procedures (Fig. 12). They habituated infants to a 480 nm light, for example, and then showed them either a 450 nm light or a 510 nm light. The babies treated the 450 nm light the same as the 480 nm light, that is, they remained habituated and did not shift their glance in a preferential looking task. However, they did shift their focus, or dishabituate, towards the 510 nm light. This suggests that a 510 nm “green” stimulus is in a separate color

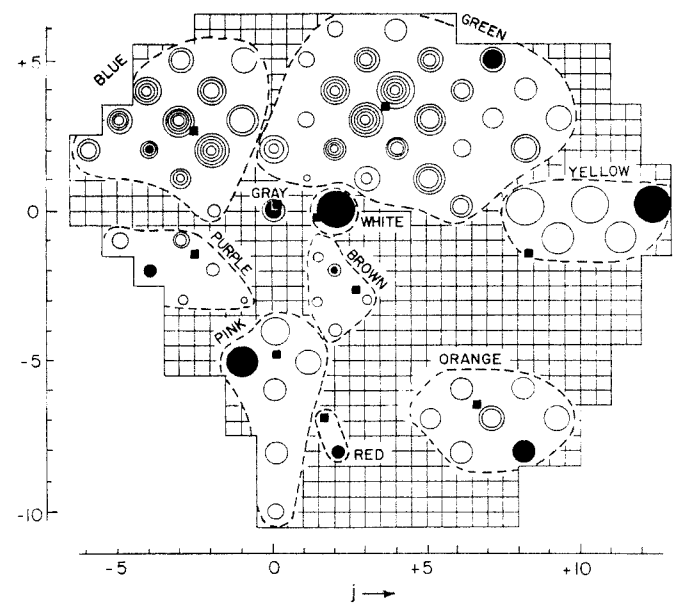


FIG. 11. Plot of Boynton & Olson's eleven basic color-naming categories using OSA color space. Circles circumference indicates lightness levels. Filled circles represent focal colors, determined by shortest response times within their category. Centroids, the arithmetic average location, are represented by the small filled squares. (Reprinted with permission from R. M. Boynton, C. X. Olson, 1987, Locating basic colors in the OSA space, Fig. 2, *Color Res Appl* 12:94–105, John Wiley & Sons, Inc.)

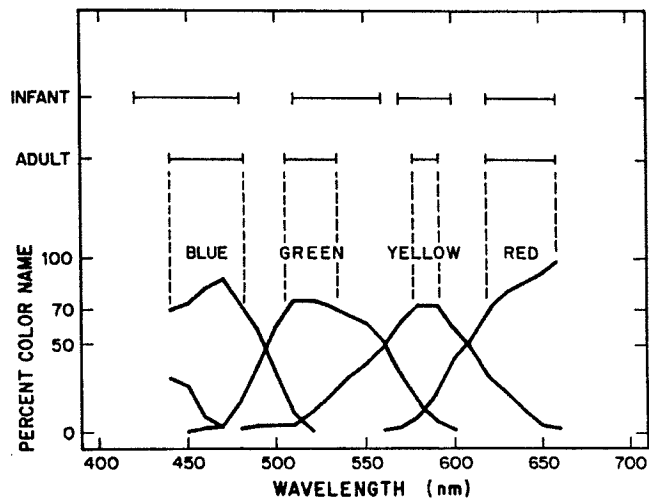


FIG. 12. Bornstein, Kessen & Weiskopf's four-month-old infant data of color categories generated by habituation procedures and adult data of color categories generated by color-naming procedures. (Reprinted with permission from ref. 22, Fig. 3.4.)

category from a 480 nm "blue" stimulus. To be sure this is what the infants were doing, in a control condition Bornstein

and his colleagues first habituated the infants to a 450 nm "blue" stimulus and then showed them other blues within the same category, say either a 430 nm light or a 470 nm light. In both these cases there was no dishabituation. Consequently, infant color categories were shown to be remarkably similar to adult color categories.

It has also been shown that Berlin & Kay's¹ focal colors are stable for five and one-half year olds and eight and one-half year olds, but their color boundaries are more variable (Fig. 13).²³ For example, the cross-over point between blue and green is 492 nm, while it is 570 nm for green and yellow. A cross-over point is when one color is reported 50% of the time and the other color is reported 50% of the time in a forced-choice paradigm where a subject must label a stimuli as either green or blue; or either green or yellow. However, the boundary width, or the distance between the 75% points decreases with age. That is, the blue-green boundary width, which is 3.5 nm for three-year-olds, reduces to 1.9 nm by age 74. Likewise, the green-yellow boundary width decreases from 4.6 nm to 3.6 nm over the life span. This brings up several interesting issues related to child development and its relationship to the evolution of language.

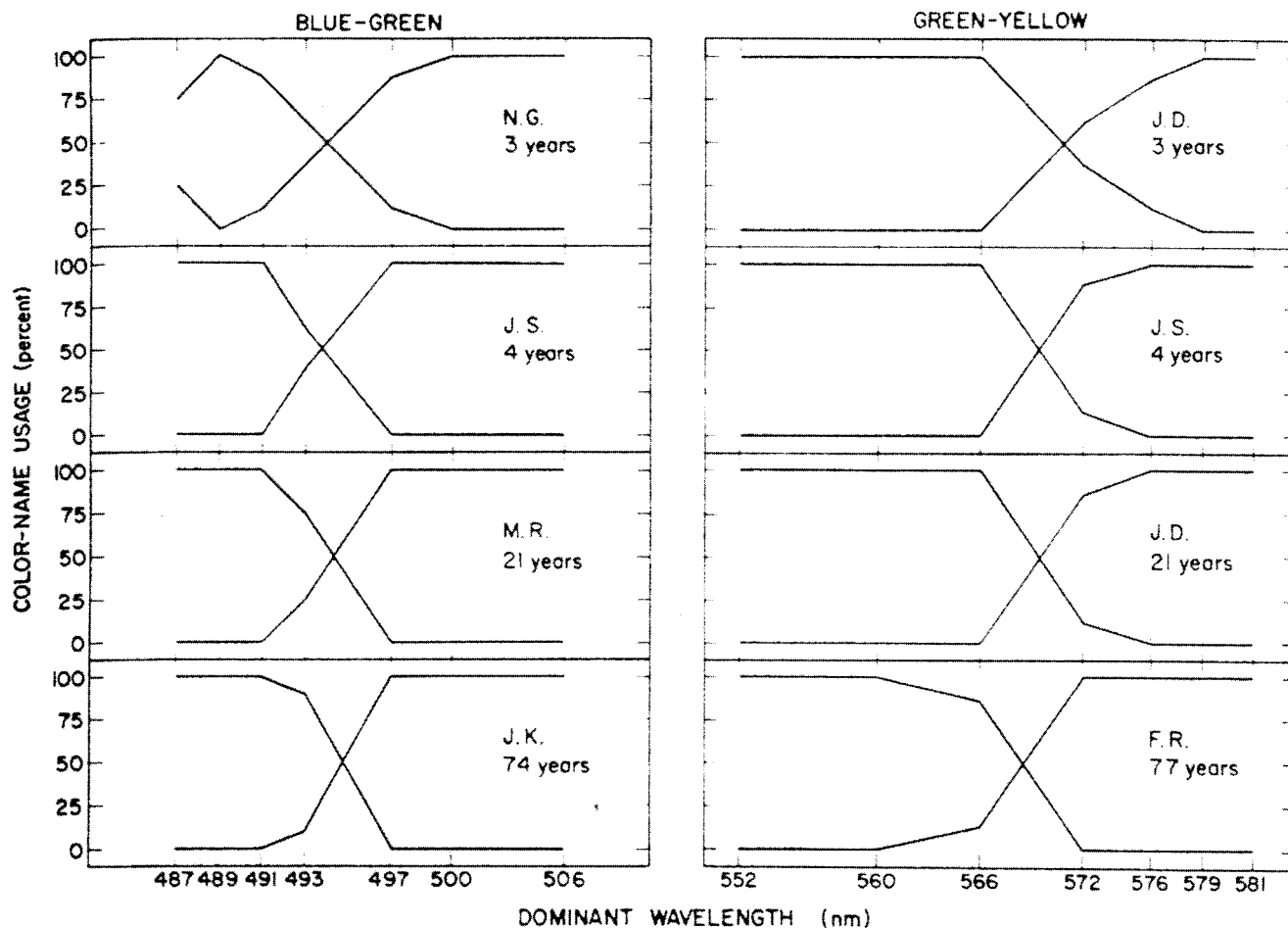


FIG. 13. The cross-over point of color-name usage and boundary width between blue-green and green-yellow for various ages. As age increases, boundary width decreases. (Reprinted with permission from L. A. Raskin, S. Maital, M. H. Bornstein, 1983, *Perceptual Categorization of Color: A Life-Span Study*, *Psychological Research* 45:135-145.)

Simon and Binet²⁴ best state the problem of color-naming acquisition as follows:

“The young child distinguishes, recognizes, and easily matches without the least hesitation the most delicate shades of color, and has nothing to envy in the adult so far as the color sense is concerned; it is the verbalization of his color sense, if we may so express it, in which he is defective” (pg. 215).

In the 1911 version of Binet and Simon’s Metrical Scale of Intelligence, about half the seven-year-old French children could name the four primary colors. Today the average American child can do this by age four. This difference is attributable to cultural changes, such as the introduction of wax crayons in school and children’s programs on television. Supporting this notion, Synolds & Pronko²⁵ showed that six year olds in school are four times as likely to correctly label a color compared to six year old children who have not been to school. Likewise, Kirk and his colleagues²⁶ found only 25% of disadvantaged head-start children could correctly name six colors, but 79% of advantaged nursery-school children could.

More to the point, it is clear from the work of Bornstein²² and others that by four-months a child can discriminate colors. Yet most children must be at least five years of age to reliably and consistently label those same colors. Young children do recognize that color is a separate domain of experience and readily identify it as such. So asking the question “what is *this* color?” readily elicits some color term, even though often incorrect. Miller & Johnson-Laird²⁷ explain that this process of learning to name colors is complicated, because a child must first establish certain color landmarks and then must locate any color with respect to those landmarks. This implies that children must abstract an appropriate attribute of an object and anchor that color experience to some internal frame of reference. Concurrently, they must discover which words are relevant to that frame, and learn which location in that frame a particular color goes with which term. Whitfield²⁸ performed a clever experiment with adults demonstrating this parallel process of framing one’s language to best fit focal colors in color space (Fig. 14). He used a technique called a “*linguistic hedge*” in which subjects are shown two colors, “A” and “B” and asked to fill in the blanks to the statement; “BLANK is almost BLANK.” That is, “this nonstandard red color is almost this standard red color.” If the two colors are equally salient linguistically, as well as perceptually equivalent, there is a 50% chance that A precedes B and a 50% chance that B precedes A. What Whitfield found, however, are color asymmetries, where the Munsell color chips in the right-hand columns in Fig. 14 correspond to Berlin & Kay’s¹ eight focal colors, thus making them the “standard colors.” Subjects are more than 75% likely to complete the sentence in the following fashion: “This (right-hand) color (in Fig. 14) is almost this (left-hand) color.” This implies that an internal frame of reference exists for each color to relate colors to one another.

Given the nature of the task involved, it should not be surprising that children need so much time to learn how to

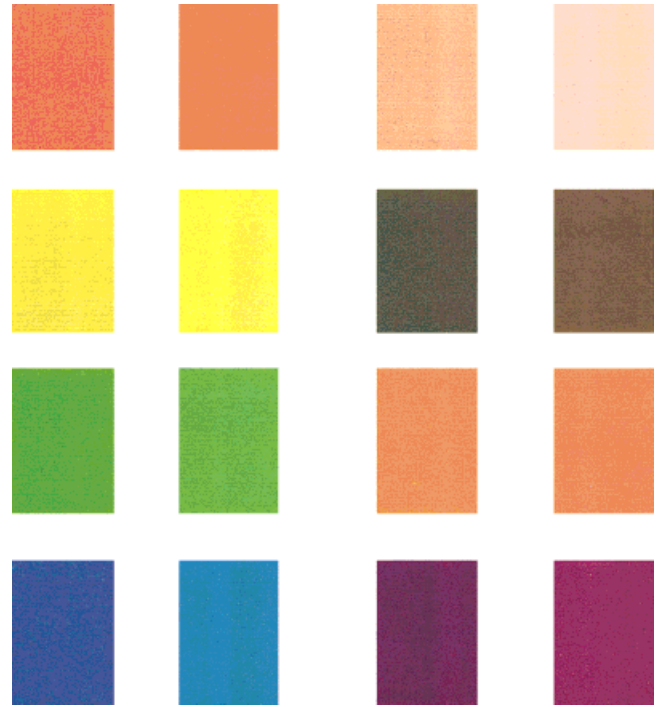


FIG. 14. Whitfield’s task where the right-hand Munsell patch (which corresponds to Berlin & Kay’s focal colors) is more than 75% likely to complete the sentence in the following fashion: “This (right-hand) color is almost this (left-hand) color.” It implies that Berlin & Kay’s focal colors serve as an internal frame of reference to relate colors of the same category.

determine focal colors and boundary colors. Their ability to learn how to label emotions, for example, probably follows a similar two-fold process and takes even more time to master. Unlike what Berlin & Kay¹ propose however, in 1977 Bartlett²⁹ showed that children acquire color names in an essentially arbitrary order. Still, when Corbett & Davies³⁰ asked people to list the color terms that first come to mind, they found that Hering’s primaries got mentioned first. So there may be some truth to the notion that color categories are biologically based on opponent processes.

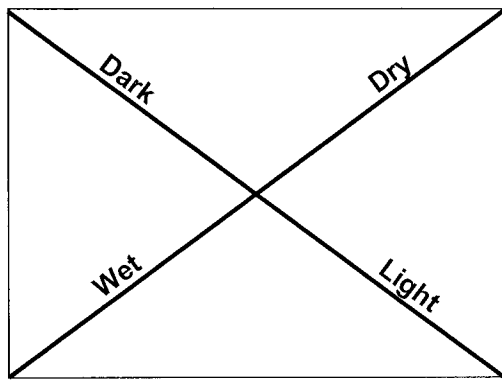
CONCLUSIONS

A central tenet of naïve realism is that color naming is the subsequent act of demarcating and labeling directly perceived colors and boundaries. However, work with children suggests that learning color names is as much a culturally learned event as a biological event. Thus, the internal representation of a color category must be linked with the biological sensations that are generated by specific wavelengths. This linking may not be isomorphic. Color categories may be either mediated or interpreted by the human mind.

This makes the Universalist’s position (that the underlying perceptual structure of color categories is what all cultures link color names to) only partially true. It may work for the color-opponent processes, that is, the six Hering primaries: black, white, red, green, yellow, and blue. However, the later five basic color categories (orange, purple, gray, pink and brown)

Mabi:ru

Marara



Malatuy

Malagti

FIG. 15. Harold Conklin's Hanunoo subject's color terms, which differentiates lightness vs. darkness and wetness vs. dryness. These color categories depend on other qualities of the objects being perceived such as texture and succulence.

are likely to be more culturally determined. Likewise, the evolution of a twelfth color category, such as Boynton & Olson's²⁰ peach/tan/salmon, may depend on the parallel development of having the requisite open perceptual region in OSA color-space to serve as a bridge, and a common agreed upon word to reference that region of space.

In closing, it is important to realize that Berlin & Kay¹ may not have the final word. Work by Harold Conklin¹³ with the Hanunoo, a Malayo-Polynesian culture of the Philippines, showed that they have a Stage III language. However, it is not divided in the typical way that Berlin & Kay would have predicted. It had four Level I terms with foci in black, white, red, and green. However, what is actually being differentiated is lightness vs. darkness and wetness vs. dryness (Fig. 15). This makes color naming dependent on other perceptual qualities of the objects being categorized. This differs from the traditional concept of color being a complex percept in that it combines colors with states of nature. So, for example, "(ma)biru" denotes darkness, that is black, violet, indigo, blue, dark green, and dark gray. "(Ma)lagti" denotes lightness, which is white and light tints. "(Ma)rara" denotes dry objects typically colored maroon, red, orange, and yellow; while "(ma)latuy" denotes fresh objects typically colored light green, yellow, and light brown. Therefore, given the Hanunoo geography and culture, a shiny, wet, brown-colored section of newly cut bamboo is malatuy (not marara); whereas dried out or mature plants (like parched corn) are marara. Their language separates hue and chromaticity from texture and succulence, because these qualities are so important in their culture.

So, the next time someone tells you the color of something, think carefully. What they say they see depends in part upon the language they speak.

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