Explaining Basic Color Categories

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Abstract

This paper surveys several lines of evidence that suggest a strong connection between the mechanisms of color vision, perceptually elementary hues, and naming basic colors. But important questions remain about the linkage between the shared human attributes of color perception and the development and structure of cross-cultural basic color categories.

Explaining Basic Color Categories

1. Preliminaries

There are indeed many properties of color categories that are functions of language and culture. But to claim that none of the significant ones are biologically based, as some cultural relativists do, seems to me to fly in the face of the facts. What we have here is a variation of the old nature-nurture debates. The proper way to handle such questions is to tease out the strands that are primarily due to nature from the strands that are mostly due to nurture. In this article I shall examine some features of color categorization that transcend the idiosyncrasies of particular languages. These features seem to depend upon similarities and differences of perceived colors. In some cases, perceptual psychologists have provided an idea of what the mechanisms underlying them might be. In other cases, the mechanisms underlying color phenomena have been overlooked by color categorization research, due in part to the fact that they are ill-understood even among researchers of color perception.

Some features of the opponent-process theory of color vision will be important for our discussion, so I shall outline them briefly. For fuller introductory treatments, see chapter 3 in Hardin and Maffi (1997) or Hardin (1988). The first step in color vision is the absorption of light by three classes of retinal cells, the cones. One cone class is sensitive to shortwave light, another to light of medium wavelength, and a third to longwave light. Post-receptoral cells combine and compare (subtract) the outputs of these cone to yield a red/green channel, a blue/yellow channel--the chromatic channels--and a light/dark, achromatic channel. The chromatic channels are configured antagonistically, so that when the red/green channel is excited, red is signaled, whereas when the channel is inhibited, green is signaled. Excitation of the yellow/blue channel yields yellow, and inhibition yields blue. When the excitation and inhibition of the channel are balanced, the result is achromatic. It follows from this configuration that red and green cannot be seen together, nor can blue and yellow. But the red/green and blue/yellow channels operate independently, so the red/green channel can signal red while the blue/yellow channel signals yellow. The result is a perception of reddishness and yellowishness together, i.e. orange. Colors such as orange or purple that perceptually contain constituents of other colors are *binary* colors. Colors that have no other colors as perceptual components are *unitary*, or, to use the more common terminology, *unique* colors. For example, a unique red is a red that is neither bluish nor yellowish. The perception of unique red occurs when the red/green channel is in an excited state while the yellow/blue channel is in equilibrium, so that there is neither a bluish nor a yellowish component. There are, then, four chromatic colors of unique hue: red, yellow, green, and blue. To these we shall add the fundamental achromatic colors, black and white, and call these distinguished six colors *the Hering elementary colors*, in honor of the founder of opponent-process theory, Ewald Hering (1878, 1964).

It is important not to confuse perceptual components with physical components. A light that looks yellow can be perceptually pure, appearing neither reddish nor greenish, despite the fact that the light is prepared by mixing a light that looks red with a light that looks green. People who are presented with patches of light from a spectral source and then asked to estimate the percentage of a given hue that they see *in* the patch can, with a little practice, do it easily and reliably.

2. Perceiving and Naming the Hering Elementary Colors

It is interesting to see what visual scientists Sternheim and Boynton (1966) discovered when they required their experimental subjects to use only a restricted set of hue terms to describe light samples drawn from the longwave end of the spectrum. If the subjects were permitted only the names ‘red’, ‘yellow’ and ‘green’, they were able to describe all of the samples in the longwave range, with the percentage totals for each wavelength sample adding to 100. The term ‘orange’ proved to be replaceable by terms for red and yellow, even at the wavelengths where those same subjects would in other experiments locate their best examples of orange. However, when the term ‘yellow’ was forbidden, and the terms ‘red’, ‘orange’, and ‘green’ permitted, the spectral region where most subjects would locate their best yellows, was underdescribed, with total hue estimates falling well below 100 per cent through most of the region, and typically going to zero for the spectral region which most subjects see as unique yellow. In a nutshell, whereas orange can always be described in terms of red and yellow, yellow cannot be described in terms of red, green, and orange. The same asymmetry holds between all of the Hering elementary colors on the one hand, and all of the remaining colors on the other. Names for the Hering elementary colors are necessary and sufficient for naming all of the colors, a fact that justifies singling them out as perceptually elementary.

The Swedish Natural Color System embodies these ideas for reflective samples. In the NCS, every color is characterized by its degree of resemblance to the six Hering elementary colors. Whereas the Munsell system is defined by the physical specification of the samples in its atlas, the NCS atlas is merely illustrative of the system, which is based on the ideas of the Hering colors that we carry around in our heads. Users of the NCS system such as artists, architects, and designers are able, outside the laboratory, to make fairly reliable estimates of the degree of resemblance of a color to a mental standard. This testifies to the psychological primacy of the Hering colors in real-world conditions—at least for adult speakers of modern languages.

Psychophysicists have given opponent-process theory a quantitative form. This involves measuring the relative responses of the opponent systems across the visible spectrum by use of a cancellation technique. To establish an observer’s opponent response, the observer is presented with a monochromatic test light of known wavelength, and is required to adjust the amount of a mixture light so as to cancel a perceptual component of the test light. Thus, the observer may be presented with a greenish test light of fixed wavelength and be asked to add a reddish light, also of fixed wavelength, to it until all traces of green have disappeared. The amount of the canceling red light that must be added is a measure of the strength of the observer's green response at the test wavelength.

One might expect that the outcomes of the color-naming tasks and of the opponent cancellation procedures would be correlated with each other. Werner and Wooten (1979) showed that when observers name the percentage of each of the elementary hues they can discern in a spectral stimulus, their average hue naming through the spectrum closely tracks their average opponent cancellation functions. So in this instance at least, the use of the names for the Hering elementary hue categories clearly reflects underlying perceptual mechanisms.

3. Colors in Context and Basic Color Terms

So far, we have mostly discussed naming the colors of lights, which are seen against a background of darkness. If we turn our attention to surface colors, in which colored patches are seen against a variety of backgrounds, a new class of appearances emerges, including the dark colors, such as black and navy blue, and the light colors, such as sky blue and pink. The most notable of these are the browns, which, to the surprise of many, prove to be just blackened yellows or oranges. Careful analysis shows that all of these can in fact be fully described by combinations of the names of the Hering elementary colors. However, most modern languages, such as English, Japanese, and Croatian, use a larger stock of eleven color names, with names for brown, purple, pink, orange, and gray (the *secondary basics*) added to the Hering six (the *primary basics*). In a language such as English there are many thousands of color words. What differentiates the basic terms from the rest of the stock of color words? Unlike such words as ‘rust’ and ‘blonde’, basic terms are applicable to any sort of object. Unlike words like ‘mauve’ and ‘chartreuse’, basic terms are used by all native speakers. Basic terms are used more consistently than non-basic terms, and with greater consensus. In both free and constrained color-naming protocols, these criteria have been shown to segregate eleven—or, perhaps, in the case of Russian, twelve (see Paramei in this issue)--basic terms from the rest of the color terms in a variety of languages that have well-developed color vocabularies.

Naming the 424 samples of the Optical Society of America Uniform Color Space using only monolexemic terms, Boynton and Olson (1987) found 128 consensus colors. There are striking differences between the volumes of the eight chromatic categories into which these consensus colors fall, as well as the range of lightness levels at which different colors appear. Some of the differences, such as the very small size of the red region, are artifacts of the OSA system, in which reds are under-represented. But others, such as the large volumes of blue and green, are quite striking, and also show up in the studies done for several languages by Sivik (1985, 1987) using the Natural Color System, and by Sturges and Whitfield (1995) using the Munsell system.

Insert Figure 1

Figure 1 shows the Sturges and Whitfield mapping of consensus colors on the outer skin of the Munsell space, with hue represented by the horizontal axis and lightness by the vertical axis. Increasing heaviness of the dots represents increasing Chroma. The numbers of consensus reds and purples have increased over those in the Boynton and Olson study, but the sizes of the green and blue regions remain strikingly large. If one asks why these “cool” colors should occupy large regions whereas the “warm” colors occupy much smaller ones, the obvious answer is that some lighter colors of reddish hue have got themselves called ‘pink’, and some darker orange and yellow colors have been called ‘brown’. But this only raises a further question. Why are there no basic terms for, say, light green or dark blue? Granted, Russian seems to distinguish a basic light blue, ‘goluboi’ from a basic dark blue, ‘sinji’--see Corbett and Morgan (1988)--but non-Slavic languages have not followed suit, and no language divides the green area into two basic regions.

Furthermore, ‘orange’ names a red-yellow binary, and ‘purple’ names a red-blue binary, but there is no basic term in any known language for either a yellow-green binary, or a green-blue binary. If there were no pan-human constraints on the emergence of basic terms for binaries, we would have expected that by now basic terms for either yellow-green or green-blue would have appeared in at least one of the hundreds of world languages whose color vocabularies have received study. The generality of the phenomenon suggests that certain binaries are visually more salient than others, yet the symmetry of the basic Hering scheme gives us no reason to expect this result. Here is a problem that clearly needs further investigation.

Here is another puzzle. If every color can be fully described by using the names for the six Hering elementary colors, we might expect the Hering colors to be psychologically more salient than the other basic colors. By several measures of salience—response time, consistency of naming, occurring early on lists of elicited terms—Boynton and Olson, Sturges and Whitfield, and several other researchers found that basic terms can be segregated from non-basic terms. But these same measures fail to differentiate the Hering colors from other basic colors.

As we have already seen, for spectral colors, if color names are restricted to labels for the four chromatic Hering elementary colors, hue naming tracks opponent response. How do matters stand if unrestricted color naming is used for the entire color space? Using a CRT display, Guest and Van Laar’s (2000) observers “freely named 1044 color-background combinations sampled regularly along the (u’, v’) axes of the 1976 Uniform Color Space. Three response measures—response times, confidence ratings and consistencies—were obtained. These measures were collapsed by principal components analysis into 'nameability', a single measure of ease of naming of colors." Guest and Van Laar found that with free naming, basic color terms scored distinctly higher on all three response measures than non-basic terms. Peak nameability occurs in the vicinity of the elementary Hering colors, and the nameability minima appear just where the opponent systems are changing polarity. So even for free naming of the full range of related colors, the structure of color categorization in a developed color-naming language appears to be related to underlying visual processes.

My final bit of evidence for a strong element of nativism in color categorization comes from an experiment performed by Matzusawa (1985). Two observers were presented, one sample at a time and in random order, with 215 color chips chosen from the outer surface of the Munsell color space. Each chip was shown three times to observer number one, a non-speaker of Japanese. Observer (b), a native speaker of Japanese, was asked to name the same chips in the same order, with one trial per chip. Observer (a) had been trained to recognize a focal chip for each of the eleven Berlin and Kay categories. She learned to respond to the presentation of a sample by pressing one of eleven keys, each with a special symbol. Once the presentation of the 215 chips began, neither observer was given reinforcement for a correct answer. Paraphrasing Matzusawa:

> Both observers divided the color space into eight clusters with a broad area within which a single color name was applied consistently. Observer (a) applied a single color name to 74% of 215 chips; observer (b) applied the same name to 79% of the chips. Areas of consistent color naming were separated by narrower areas in which the names applied to

the two adjacent areas were used. There were slight differences between the observers in the location of these border areas.

Insert Figure 2

The distributions of the color names for the two observers in Matzusawa's data shown in Figure 2 are unremarkable, except for one thing: observer (a) was a chimpanzee.

That a human being and a chimpanzee can agree so closely on the size, shape and location of these categories in color space is a very important argument for there being a strong biological component in basic color naming. Nonetheless, it is important to bear in mind that Ai, the chimpanzee, was given focal specimens and asked to generalize, whereas human beings are given names, and asked to find focal examples.

4. Focal Colors and Elementary Colors

Before Debi Roberson (2000) restudied focal learning in New Guinea, and failed to replicate Rosch's famous results that gave rise to her prototype theory of category formation (Heider 1972a,b), we thought that we knew that people tended to focus their most basic color categories on the Hering elementary colors, and that color categories are formed by judgements of the degree of resemblance to those elementary colors (see Roberson's contribution in this issue). The elementary colors are singled out as foci because they are more salient and more easily learned and remembered than their neighbors, even in the absence of words to describe them. Or so we had supposed.

Insert Figure 3

Just what role the Hering elementary colors play in organizing the color categories that contain them is something that ought to be investigated more thoroughly. For now, it is important to point out that they certainly play a prominent part in the way that diverse languages structure their color categories. Robert MacLaury (1997), who has probably done more field work on color categorization than anybody else on the planet, has compiled data on focal selection from Berlin, Kay, and Merrifield’s (1985) World Color Survey for 107 of the 110 minor and tribal languages covered by the survey. The selection targets for the World Color Survey were 330 chips of maximum Chroma, representing the outer skin of the Munsell array. The are represented in the top diagram of Figure 3, with the numerals in each cell specifying the Munsell Chroma of the chip. Every color chip that was chosen by any informant for any color term whatsoever—basic or not— is included in the summary. There were 15,186 focal selections represented, 10,644 of which were focused on a single rather than multiple chips. The 10,644 are represented in the middle diagram, along with the number of choices on each chip. The bottom diagram is a histogram of selections by Munsell Hue column. The R, Y, G, and B points are mean focal hues for primary basic categories in English as well as other eleven basic-term languages. They are close to the mean unique hue points as determined by other studies.

It is important to note that there is substantial interobserver variability of unique hue loci as well as substantial variability in focal choices. Both are of approximately equal magnitude. There are small, significant differences between mean focal choices (as well as unique hue choices) made by speakers of different languages, but these are always smaller than the variance of focal and unique hue choices among the users of the same language. For a thorough discussion see Webster et al. 2002.

5. The World Color Survey

Berlin, Kay, and Merrifield's World Color Survey, which we have just mentioned, has gathered color-naming data under a uniform protocol from 25 monolingual speakers for each of 110 exotic languages. It is a singular resource for comparing color categories across cultures. Informants name each of 330 Munsell chips presented singly and in random order, and then choose the best example of each named color from a single miniaturized array that contains all 330 colors. Berlin and Kay have attempted to find patterns the WCS data that extend across languages. They have long since abandoned the evolutionary sequence that they proposed in their influential 1969 book, *Basic Color Terms*. In that work, they conceived of the formation of categories as being a series of encodings of the basic colors (Fig. 4):

Insert Figure 4

Not long after publication of *Basic Color Terms*, Kay and McDaniel (1978) reflected particularly on Rosch's description of Dani color terms and decided that something more remarkable was going on. It seemed to them that languages with few basic color terms should be understood as employing macro-categories that ought to be glossed as disjunctions of English categories rather than being glossed by the English basic terms with approximately the same focus. Thus Dani, the only known example of what they referred to as a "Stage I" language, has two basic color terms, or at least seem to have, when Rosch worked with the Dani half a century ago. One of these is used to name the warm or light colors, and should be glossed as "Red or Yellow or White" rather than "White", as they had previously done. The other Dani terms, used to name the cool or dark colors, should be glossed "Green or Blue or Black" rather than as "Black."

Insert Figure 5

According to Berlin and Kay's most recent scheme (Kay, Maffi and Merrifield's1997), depicted in Figure 5, a Stage II language arises from a Stage I when the very light colors are separately named: Red or Yellow, constituting a "warm" category, White, and Black or Green or Blue, a "cool" category that encompasses very dark colors as well. In the chief variant of Stage III, a separate Black category emerges, and in Stage IV, the "warm" category has subdivided, but not the "cool" category. In the figure, the numerals indicate the number of languages that are, respectively, at the stage in question or in transition to the next stage.

This "main sequence" accounts for 83% of the WCS languages. In each case, one stage is derived from another by a partition of the macro-categories with a corresponding retraction of the denotation range of a basic term that originally spanned the larger region. For instance, for some Stage V languages, a term that originally ranged over both blue and green might be restricted to an area roughly similar to the range of the English term green, with a new term for the blue range. After Stage V, the so-called secondary basic terms—gray, orange, purple, brown, and pink— come to be represented, but in no canonical order. As they are introduced, the primary basic terms of course contract in range; for instance, regions that have come to be named by an orange term would no longer fall under the denotations of the terms covering the red and yellow areas.

6. More Puzzles

The remaining 19 languages in the World Color Survey are accommodated by a few complications to the scheme, which I shall not go into here. I want instead to direct your attention to two interesting features of the developmental sequence that seem to me to call into question Hering’s pronouncement that the elementary colors are, save for their lightness and darkness, equally unlike each other. The data from the World Color Survey suggest first, that red and yellow are more like each other than either is like blue or green, and second, that green is more like blue than red is like yellow.

For the first point, consider the Stage I initial partition of color space into warm-with-light colors and cool-with-dark colors. The division seems to us to be a very natural one. But is this a mere environmentally-induced association across sensory modalities, or are the words ‘warm’ and ‘cool’ just convenient labels for a perceived similarity that groups reds and yellows together, and greens and blues together?

Insert Figure 6

I believe it to be the latter. I have two reasons. The first, derived from studies of semantic differentials by Sivik and Taft (1991), is that warm-cool ratings of NCS chips are similar across speakers of Swedish, Croatian, Greek, and English. Orange is rated warmest, unique blue coolest, and the neutral points are at green-yellow and red-blue. The other is in an unpublished study by Katra and Wooten (1996), in which subjects rated eight equally spaced NCS chips by relative warmth and coolness (Fig. 6). Their average ratings were compared with chromatic channel activation responses. The warm-cool responses tracked the chromatic responses remarkably well, suggesting a biological rather than an environmental source for the perceived difference. Notice that the warm-cool curve crosses the zero axis at NCS G50Y and R50B.

Insert Figure 7

The Munsell equivalents are 5GY and 2.5P, a nice fit for the boundaries of ‘Nol’, the blue-with-green category of Berinmo, the Dani language that Roberson, Davies, and Davidoff (2000) recently investigated (Fig. 7). Berinmo’s ‘Nol’ category is pretty typical of blue-with-green categories in other world languages.

Now consider the following question: If green is no more like blue than red is like yellow, why is it that among the WCS languages there is not a single example of a language that has both separate terms for blue and green as well as a common term for red and yellow? By contrast, there are 41 languages that have separate terms for red and yellow, as well as a single term that covers both green and blue. This could be accounted for if we suppose that people tend to see blue and green as being more similar to each other than red and yellow are to each other. But then why do they see them this way?

The contrasting basic categorical fate of red and green is like a soap opera. Red consorts freely with her neighbors—yellow and blue, and black and white—and leaves many progeny: orange, purple, pink, and brown. Green, on the other hand, keeps herself intact. Flirting with yellow, though devoted to blue, she has no offspring. I, for one, would like to know why. As a philosopher, I am a consumer of data rather than a producer. So I hope that there is somebody reading these words who is sufficiently unorthodox to take these questions seriously, and sufficiently well funded to try to answer them.

References

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

Berlin, B., P. Kay, and W.R. Merrifield 1985. Color term evolution: Recent evidence from the World Color Survey. Paper presented at the 84th Annual Meeting of the American Anthropological Association, Washington, D.C.

Boynton, R.M. and C.X. Olson 1987. Locating basic colors in the OSA space. *Color Research and Application* 12: 94-105.

Boynton, R.M. 1997. Insights Gained from Naming the OSA Colors. In C.L. Hardin and L. Maffi (eds.) *Color Categories in Thought and Language*. Cambridge: Cambridge University Press.

Corbett, G. and I. Davies 1997. Establishing basic color terms: Measures and techniques. In C.L. Hardin and L. Maffi (eds.) *Color Categories in Thought and Language*. Cambridge: Cambridge University Press.

Corbett, G. and G. Morgan 1988. Colour terms in Russian: Reflections of typological constraints on a single language. *Journal of Linguistics* 24: 31-64.

Guest, S. and D. Van Laar 2000. The structure of colour naming space. Vision Research 40, n. 7: 723-734.

Hardin, C.L. 1988. *Color for Philosophers: Unweaving the Rainbow.* Indianapolis: Hackett Publishing Company.

Hardin, C.L. and L. Maffi (eds.) 1997. *Color Categories in Thought and Language*. Cambridge: Cambridge University Press.

Heider [Rosch], E. 1972a. Universals in color naming and memory. *Journal of Experimental Psychology* 93(1): 10-20.

Heider [Rosch], E. 1972b. Probabilities, sampling and the ethnographic method: The case of Dani colour names. *Man* 7(3): 448-466.

Hering, E., 1878, 1964. *Outlines of a Theory of the Light Sense*, translated by L,M, Hurvich and D. Jameson. Cambridge, MA: Harvard University Press.

Katra, E. and B. R. Wooten 1996. Perceived lightness/darkness and warmth/coolness in chromatic experience. Unpublished MA thesis, Brown University.

Kay, P. and B. Berlin. 1997. Science ≠ Imperialism: There are nontrivial constraints on color naming. *Behavioral and Brain Sciences,* 20(2), 196-201.

Kay, P. and C.K. McDaniel 1978. The linguistic significance of the meanings of basic color terms. *Language* 54(3): 610-646.

Kay, P., B. Berlin, and W.R. Merrifield 1991. Biocultural implications of systems of color naming. *Journal of Linguistic Anthropology* 1(1): 12-25.

Kay, P., B. Berlin, L. Maffi and W.R. Merrifield. 1997. Color naming across languages. In In C.L. Hardin and L. Maffi (eds.) *Color Categories in Thought and Language*. Cambridge: Cambridge University Press.

MacLaury, R.E. 1992. From brightness to hue: An explanatory model of color-category evolution. *Current Anthropology* 33: 137-186.

MacLaury, R.E. 1997. *Color and Cognition in Mesoamerican Languages: Constructing Categories as Vantages*. Austin: University of Texas Press.

Matsuzawa, T. 1985. Colour naming and classification in a chimpanzee (*Pan troglodytes*). *Journal of Human Evolution* 14: 283-291.

Roberson, D., I. Davies, and J. Davidoff. (2000). Colour categories are not universal: Replications and new evidence from a stone-age culture. *Journal of Experimental Psychology: General* 129: 369-398.

Sivik, L. 1997. Color systems for cognitive research. In C.L. Hardin and L. Maffi (eds.) *Color Categories in Thought and Language*. Cambridge: Cambridge University Press.

Sivik, L. 1985. Mapping of color names in NCS. *Proceedings of the 5h Congress of the AIC,* Monte Carlo, Monaco.

Sivik, L. and C. Taft 1990. Semantic variables for the evaluation of color combinations—An analysis of semantic dimensions. *Göteborg Psychological Reports* 19(5).

Sivik, L. and C. Taft 1991. Cross-cultural studies of color meaning. *Proceedings of AIC-conference on Color and Light '91,* Sydney.

Sternheim, C.E. and R.M. Boynton 1966. Uniqueness of perceived hues investigated with a continuous judgmental technique. *Journal of Experimental Psychology* 72: 770-776.

Sturges, J. and T.W.A.Whitfield. (1995). Locating basic colours in the Munsell space. *Color Research and Application* 20, n. 6: 364-376.

Webster, M.A. et. al. (2002). Variations in normal color vision. III. Unique hues in Indian and United States observers. *Journal of the Optical Society of America* A 19, 1951-1962.

Werner, J.S., and B.R. Wooten (1979). Opponent chromatic mechanisms: Relation to photopigments and hue naming. *Journal of the Optical Society of America* 69, 422-434.

Figure Captions

Figure 1. Mapping of consensus colors on the outer 'skin' of the Munsell space, with hue represented by the horizontal axis and lightness by the vertical axis. Increasing heaviness of dots represent increasing Munsell chroma. Reproduced Figure 1 from Sturges, J. and T.W.A.Whitfield. (1995). Adopted with permission

Figure 2. The distribution of color names assigned to the stimulus grid of the Munsell space for two observers. Observer (a) is a chimpanzee, observer (b) is a human participant. Reproduced Figure 5 from Matsuzawa, T. (1985). Adopted with permission.

Figure 3. Panel a's (top panel) numerals represent Munsell Chroma indices for stimuli typically used in the Munsell outer 'skin' grid. Panel b's values (middle panel) are frequencies with which specific samples were identified as focal selections. Panel c (bottom panel) shows a histogram of observed average focal hues for primary basic category selections (e.g., Red, Yellow, Green & Blue glosses) according Munsell hue columns (horizontal axis).Reproduced Figure 3 from R. E. MacLaury available online at: http://www.sas.upenn.edu/~maclaury/VT-Outline.pdf. Adopted with permission.

Figure 4. Berlin and Kay's original evolutionary sequence of basic color terms. Reproduced Figure 1. from Kay and Berlin (1999). Adopted with permission.

Figure 5. A revised formulation of the progression of color term nomenclature from Stages I to

V of the basic color term theory. Reproduced Figure 2 from Kay, Merrified and Maffi (1997). Adopted with permission.

Figure 6. Chromatic channel activation response data (curve with square symbols) compared with participant's warmth-coolness judgment data (curve with circle symbols) for an interval of Natural Color System stimuli ranging from R50B (i.e., a 'purple' hue) to R (i.e., a 'red'). Reproduced Figure 9 from Katra, E. and B. R. Wooten (1996). Adopted with permission.

Figure 7. The blue-with-green category of Berinmo speakers represented by the 'Nol' contour depicted on the Munsell outer 'skin' stimulus grid. Reproduced Figure 2 from Roberson, D., I. Davies, and J. Davidoff. (2000). Adopted with permission.

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