Why GRUE? An Interpoint-Distance Model Analysis of Composite Color Categories

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This article applies the interpoint-distance model (IDM) to explain composite color categories that continue to challenge existing models in the literature. Using universal cognitive principles and heuristics suggested in the IDM, analyses demonstrate that the composite category blue-green (or GRUE) seen in many languages is one of several natural coding configurations expected in the development of a color lexicon for communicating about color sensations within a given ethnolinguistic society. Using the IDM, these enigmatic composite color categories can be explained and integrated into an updated view of the psychological processing responsible for similarities in cross-cultural color processing. The IDM also allows for revision of existing theories and increases our understanding of the cognition that underlies individuals' color naming, categorization, and concept formation.

Keywords: *categorization; composite categories; cognitive universals; color naming; cross-cultural similarities; GRUE*

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Color categorization is arguably one of the most widely used vehicles for understanding general cognitive concept formation and psychological classification behaviors. Nevertheless, traditional theories have had difficulty modeling the composite categories frequently observed in color lexicons across cultures. Here we propose that these difficulties arise from too exclusive a focus on hue, which in turn originates from a widely held view reflecting a form of physiological determinism for categorical color perception. Berlin and Kay's (1969) classic analysis created a boom in the scientific study of cross-cultural color naming and categorization. Their theory promoted a form of linguistic universality based on biological determinism. Their subsequent research included a *fuzzy-set theory* approach to color naming, detailing how color examples can be members of a color category to some degree (especially in category boundary regions) and making specific the linkage of color categories to *fundamental neural response* properties of human visual processing (Kay & McDaniel, 1978, p. 637).[1] Kay and McDaniel (1978) also formalized definitions for primary, derived, and composite color categories. Accordingly, they defined *primary color categories* based on six biological primitives, *derived color categories* as the fuzzy intersection of primary color categories (e.g., orange, purple), and *composite color categories* that are the fuzzy union of primary color categories (e.g., light-warm, dark-cool, and GRUE) (Kay & McDaniel, 1978, p. 637). The present article focuses on the latter class of categories, namely, composite color categories.

Anticipating Kay and McDaniel's (1978) fuzzy-set formalization of *composite* color categories, Kay (1975) described a need for theory to account for results then appearing in the literature. In particular, changes to theory were needed to accommodate the composite category GRUE (a category including green or blue) in his universal hierarchy model of color lexicon development.[2]

Kay (1975) describes the impetus for modeling composite GRUE as follows:

> Berlin & Kay (1969: 42) noted that Japanese *ao* 'blue' appears on the basis of internal reconstruction to be older than *midori* 'green', and that moreover there is evidence that *ao* once included greens

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> as well as blues. This suggested that at an earlier stage Japanese would have had a GRUE term (*ao*) with the focus in blue and would thus have violated the hypothesized sequence of encoding of foci by having encoded blue before green. We were not then willing to abandon (I) [the 1969 sequence], which specified green before blue, on the basis of this single inferential counter-example. Since that time, however, further cases in which blue is encoded before green or contemporaneously with green have come to light. Berlin & Berlin (1974) report that Aguaruna *wínka* GRUE has virtually all (97 percent) of its focal responses in blue. In addition, it may be recalled that Berlin & Kay (1969: 10f) report that approximately one-fourth of forty Tzeltal informants placed focal *yǎs* in blue; similarly Heinrich (1973) indicates that Eskimo *tungu* - GRUE focused in both green and blue, (never in blue-green) with some (most?) informants showing a preference for blue. Dougherty (1974) reports Futunese *wíwi* GRUE focused in both green and blue, preponderantly the latter. As these authors point out, the new data require a revision of the theory to allow the blue focus to be encoded before or simultaneously with the green focus. . . . These facts about color foci have an important implication, namely that the operative element in the sequence at stage III is neither the focus green nor the focus blue but the *category* GRUE. (p. 258-260)

To account for these composite GRUE developments, Kay's (1975) revised theory shifts the emergence hypothesis emphasis from specific color "foci" (Kay, 1975, p. 257, Figure 1) to "categories" (Kay, 1975, p. 260, Figure 4). This is illustrated in Kay's Figure 4, reproduced here as Figure 1. Compared to its precursors, the sequence in Figure 1 defines a new operative element at Stage III as a *category* (i.e., GRUE) rather than strictly emphasizing *foci*. Kay described the theory's shift from a "focus" emphasis:

> The category GRUE may be accorded a basic color term either before or after the yellow focus is encoded, but GRUE is never split into green and blue and labeled with two basic color terms until after the yellow focus is named at the basic level. (p. 260)

Thus, a green-blue composite category is accommodated by the theory.

Linguistic and perceptual distinctions between green and blue proved to be fertile ground for empirically testing Whorfian-inspired theories about the influences of language on perceptual similarity judgments. Kay and Kempton (1984) were among the first to

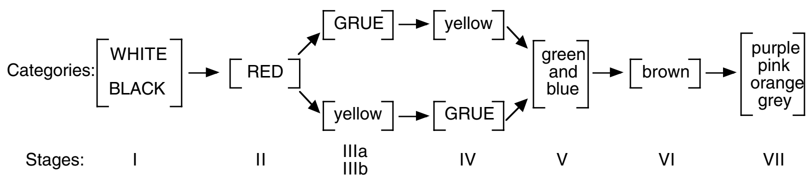

Figure 1: A Reproduction of Kay's (1975) Revised Sequence in Which Category Foci Are Encoded Semantically in Color Lexicons

SOURCE: Adapted from Kay (1975, p. 260, Figure 4), with permission from Cambridge University Press.

show that for judged triadic comparisons of perceptually similar green and blue Munsell chips, there

> appear to be incursions of linguistic categorization into apparently nonlinguistic processes of thinking, even incursions that result in judgments that differ from those made on a purely perceptual basis. Thus, . . . the English speaker judges chip B to be more similar to A than to C because the *blue-green* boundary passes between B and C, even though B is perceptually closer to C than to A. (p. 77)

For the case of these green-blue stimuli, their developing model of color naming then came to express the culturally relative view, "first, that languages differ semantically but not without constraint, and second, that linguistic differences may induce nonlinguistic cognitive differences but not so absolutely that universal cognitive processes cannot be recovered under appropriate contextual conditions" (Kay & Kempton, 1984, p. 77). Subsequently, MacLaury (1986, 1987) empirically demonstrated robust yellow-green composite categories in his Mesoamerican survey data, and using data from the World Color Survey, Kay, Berlin, and Merrifield (1991) further advanced the visual processing-based explanation for composite categories. New evidence of robust *composite* categories continues to be found in the World Color Survey and recent empirical investigations (e.g., Roberson, Davies, & Davidoff, 2000). A number of composite category examples can be found in the extensive data presented by MacLaury (1997a) and in the work of Kay and colleagues cited here.

Despite these advances, composite categories, such as GRUE and yellow-green (or Y-G), continue to represent a modeling challenge for color-naming theory. The difficulties arise because such composite categories are not easily explained by any accepted theoretical rationale (i.e., classic opponent-colors theory or perceptual processing salience ideas). Nor are there clear culturally based reasons why a composite GRUE or Y-G category should emerge as lexicon entries prior to another category held to be *primary* by accepted theory or why such composites should commonly occur across a wide range of unrelated languages. This article explores possible reasons for existing composite categories and provides analyses that explain such category structures as naturally arising from specific cognitive universals found in color categorization behaviors. Here we ask the following: What theory of color naming can simultaneously explain both (a) languages that have different basic terms for appearances considered by theory to be *perceptually unitary* and (b) languages that have a single *composite* term for two or more *perceptually unitary* regions of color space? The cognitive universals proposed take the form of specific heuristics and principles in an Interpoint-Distance Model of color categorization. The focus here is primarily on Interpoint-Distance Model characterizations of some of the more common composite categories and their subpartitions.

The next section presents a summary of the Interpoint-Distance Model, and the third section applies the Interpoint-Distance Model to composite category naming.

THE INTERPOINT-DISTANCE MODEL

The Interpoint-Distance Model (or IDM) is an alternative to current explanations of color category–naming systems and the similarity often seen between color-naming systems from different cultures (Jameson, in press; Jameson & D'Andrade, 1997). Central to the IDM are a set of principles and general heuristics that explain (a) different paths to lexically partitioning color category areas from the wide range of possible colors seen in naturalistic, everyday circumstances[3] and (b) specific paths for defining named color category and best-exemplar regions as they vary depending on the range and extent of the color stimulus spaces used in categorization and naming tasks. Despite the name interpoint-*distance* model, the IDM places no emphasis on uniform metric scales, or Euclidean distances, linked to uniform perceptual-processing metrics as a basis for color-naming universals. Rather, the IDM emphasizes universal cognitive-processing principles, similar to "rules" or "schema," that are ideally suited for the cognitive processing and naming of color category members. The reasons for avoiding *metric* distances are detailed in Jameson (in press).

The IDM proposes that these universal cognitive principles can exert a similar influence on color-naming systems across cultures, and the degree to which cultures seem to *universally* name colors is related, in part, to their independent use of the cognitive principles proposed by this model. Importantly, the IDM also gives sociocultural influences a direct role in the development and maintenance of color-naming and categorization systems. How these different cognitive and sociocultural influences combine in the IDM framework is illustrated in the examples described below.

The IDM takes as its foundation certain assumptions that are well illustrated by Harold Conklin's (1955) introductory comments in his report on Hanunóo color categories:

> In our technical literature definitions state that color is the evaluation of the visual sense of that quality of light (reflected or transmitted by some substance) which is basically determined by its spectral composition. The spectrum is the range of visible color in light measured in wave lengths (400 [blue-violet] to 700 [deep red] millimicrons). The total color sphere—holding any set of external and surface conditions constant—includes two other dimensions, in addition to that of spectral position or hue. One is saturation or intensity (chroma), the other brightness or brilliance (value). These three perceptual dimensions are usually combined into a coordinate system as a cylindrical continuum known as the color solid. Saturation diminishes toward the central axis which forms the achromatic core of neutral grays from the white at the end of greatest brightness to black at the opposite extremity. Hue varies with circumferential position. Although technically speaking black is the absence of any "color," white is the presence of all visible color wave lengths, and neutral grays lack spectral distinction, these achromatic positions within the color solid are often included with spectrally defined positions in the categories distinguished in popular color systems. (pp. 339-340)

Figures 2, 3, and 4 schematically illustrate the perceptual color-space constructs Conklin (1955) describes using components of the Munsell Color Order System.[4] Indeed, the dimensions Conklin describes for Hanunóo color space have been described often in the literature and are generally considered by color perception

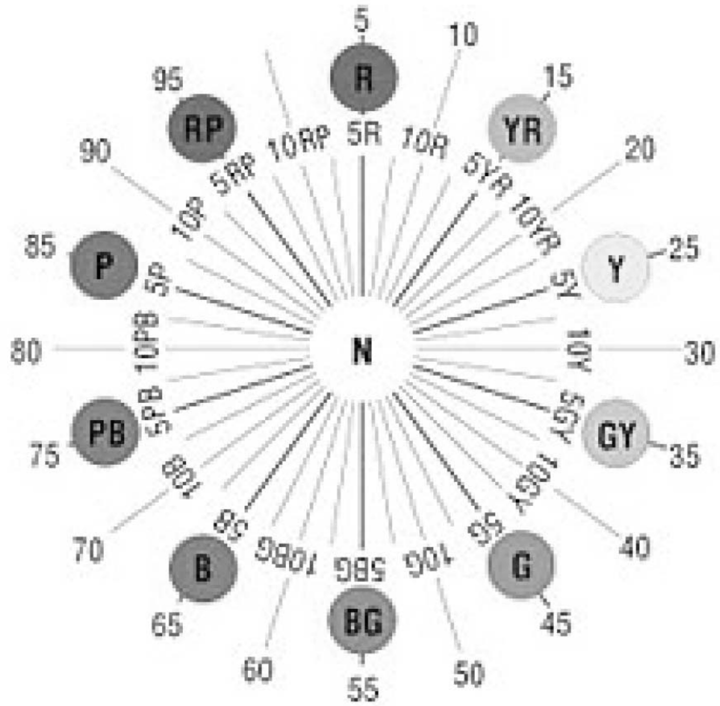

Figure 2: Munsell Hue Circle Depicting 40 Radial Hue Pages From the *Munsell Book of Color* (1976)

SOURCE: Image Credit Gretage-MacBeth Ltd., copyright 1999, Zurich, Switzerland (http://www.munsell.com). Retrieved 02/10/03.

researchers as the classic dimensions of color space (Jameson & Hurvich, 1959). Figure 2 shows a grey-scale schematic of the hue circle, as defined for the Munsell Color Order System. Figure 3 additionally illustrates a lightness dimension (Munsell "value") typically considered perpendicular to the hue circle and the radial gradient of saturation (Munsell "chroma"). Figure 4 illustrates the nonspherical shape of the Munsell solid. The irregular shape reflects lightness and saturation variation that occurs with changes in hue, and although the irregular "bumps" in the Munsell solid are in part imposed by limits imposed by printing pigments, the envelope of possible colors given by mixing visible spectra is also nonspherical. A Mercator projection of the Munsell solid surface was used as the Berlin and Kay (1969) color stimulus

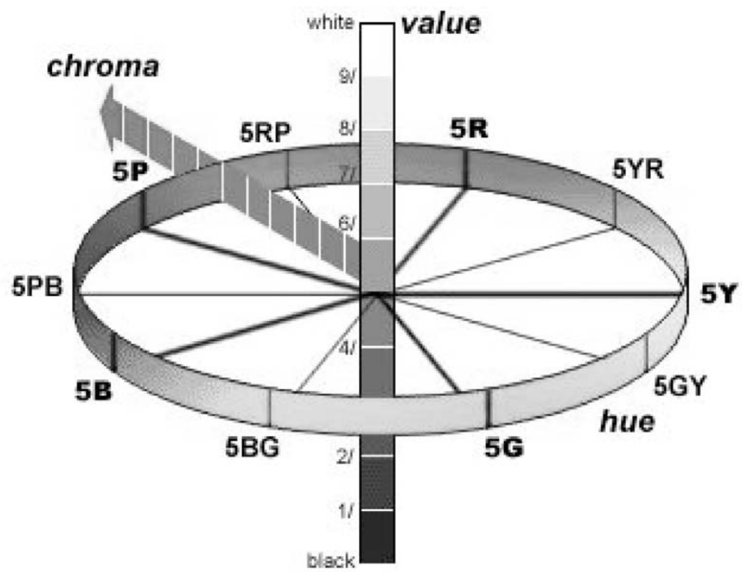

Figure 3: Axes of the Munsell Color Solid Consisting of the Horizontally Oriented Hue Circle and the Vertical Lightness Axis or Value Scale

SOURCE: Image Credit Gretage-MacBeth Ltd., copyright 1999, Zurich, Switzerland (http://www.munsell.com). Retrieved 02/10/03.

NOTE: Throughout the color system, color intensity is indexed by a chroma scale radiating from the colorless vertical axis of the solid out to the colorful surface of the system.

and is still widely used in color categorization research (see Kay & Regier, 2003; Regier & Kay, 2004, for a full-color version). Figure 5 is a grey-scale sample of a constant-hue page from the mid-blue region of the Munsell solid. Forty such pages, sampling the entire hue circle, comprise the *Munsell Book of Color* (1976). Individual color stimuli, or "chips," from the *Munsell Book of Color* are designated by Munsell notation for a hue page (e.g., 5 B), a brightness index (e.g., value = 5), and a saturation index (e.g., chroma = 7).

The three dimensions—brightness, saturation, and hue—are among those used by the IDM as perceptually related cognitive universals that, when combined with other robust universal cognitive principles, provide a foundation for color categorization and naming behaviors that many cultures share.[5]

Additional cognitive principles incorporated in the IDM are similar to those formally described by W. R. Garner (1974) in his

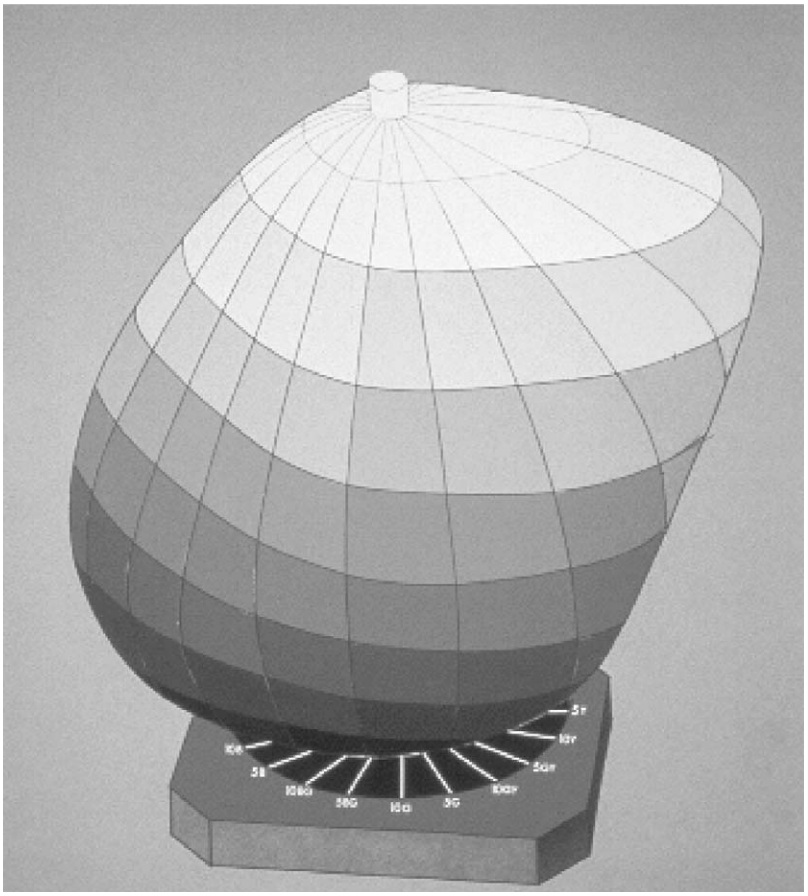

Figure 4: The Munsell Color Solid
SOURCE: Reproduced with permission from *Colour in Computer Graphics Photo CD*. MacColour Limited, copyright 1996.
NOTE: The outer surface, or “skin,” of the solid represents the most colorful (highest chroma) samples for any hue depicted.

book on the structure of information. Garner generally defines the notion of perceptual independence and cognitive separability of stimulus properties as psychological dimensions. As expressed by Garner for the classification of natural categories, “the subject classifies stimuli so that [s]he maximizes the perceived differences between classes, while at the same time maximizing the perceived similarities within classes” (p. 98). Consistent with

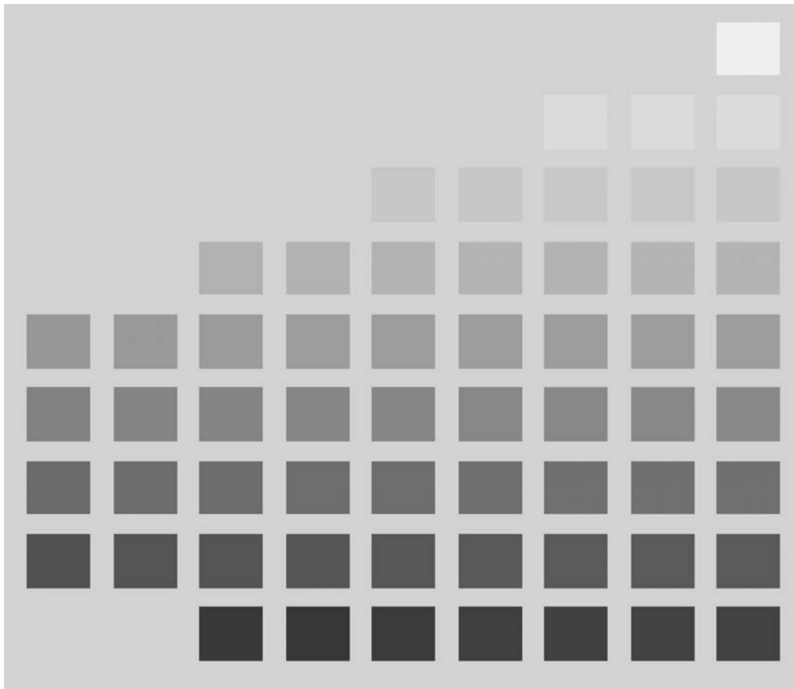

Figure 5: Radial "Slice" (as in Figure 3) Illustrating a Blue Constant Hue Page Using *Munsell Book of Color* (1976) Renotations
SOURCE: Adapted and modified with permission from http://www.uni-mannheim.de/fakul/psycho/irtel. Software CVD.exe (Irtel 1992) publicly available at http://www.uni-manheim.de/fakul/psycho/irtel/cvd.html
NOTE: The horizontal scale of chroma levels is extended beyond that represented in any published version of the *Munsell Book of Color* (1976) to illustrate the greater range of colors displayable on an emissive video display. Although extended chroma levels are shown here, actual surface samples from the *Munsell Book of Color* do not surpass chroma levels greater than 14 due to limited gamuts of printing pigments.

Garner's view, the IDM identifies relevant dimensions in actual color space (or those dimensions specific to an investigated color stimulus space) that best serve as the means for identifying and classifying stimuli on the basis of (a) their sets of perceived similarities within categories and (b) their sets of perceived differences across categories.

Dimensions for classifying color can be identified at different levels. Conklin's (1955) description of salient perceptual dimensions that serve as a basis for classification includes the perceived sections along the gradient spectrum (i.e., hue variation), gradient color purity from colorless to colorful (i.e., segmenting saturation variation), and continuous levels of perceived varying intensity (i.e., gradient brightness levels). In addition, gradient dimensions such as "shimmer to dullness," "gloss to matte," or "warm to cold" are also effective bases for differentiating between perceived color classes and for defining perceived similarities within classes (especially when such dimensions signal valuable information). The IDM also operates on dimensions that are strictly cultural such as the dimensions of "freshness to dessicatedness" or "loudness to quietness."

Of course, two cultures' dimensional emphases can differ or be highly similar,[6] but once the *dimensions* emphasized by a given culture's knowledge structure for color are known, then specific IDM principles can be used to analyze and predict the most effective color category relational structure from an information encoding standpoint. Expressed collectively, these constitute *rules*, and individually, they are *schema* (see D'Andrade, 1981; Feldman, 2003).

IDM PRINCIPLES

Briefly, two primary IDM heuristics include (a) polar symmetry (or opponency—but not the usual chromatic opponency found in the literature)[7] and (b) pressures to regularize and balance the spatial area of category partitions (see also discussion in Griffin, 2004). These two principles, in essence, lead to predictions of uniformly distributed category structures, consisting of separate categories that reflect normative partitions across the entire stimulus space, regardless of the number of color categories a language manifests. In applying these principles, the IDM would not predict the lexicalization of color space by (a) a single, large "cool" composite category that spanned color regions glossed by appearances of, say, *black, brown, green,* and *blue,* in conjunction with (b) several smaller but distinct "basic" categories each glossed by labels *white, red,* and *yellow,* as well basic terms for *burgundy, crimson, magenta, lavender,* and *violet*. Such an asymmetrically distributed structure would not represent a reasonable lexical mapping of the stimulus space from an information representation perspective. Such mappings of color lexicons to color space are not common in the world's languages, and, indeed by IDM principles, asymmetrically distributed mappings should only occur when lexicalization of the space is strictly pragmatic.[8]

Moreover, application of these two principles in effect implies that defining the first partition greatly shapes the emergence and naming of subsequent partitions in the space—this issue is central to explaining how two cultures can have different dimensional emphases and yet appear to name color space similarly.[9]

BRIGHTNESS AND SATURATION DIMENSIONS EMPHASIZED OVER HUE

The IDM differs from most of the existing theories of color-naming systems because it emphasizes foremost dimensions of brightness and saturation and, to a lesser extent, the hue circle. The IDM is compatible with D'Andrade and Egan's (1974) results showing lightness (or brightness) and saturation as more cognitively salient than hue. MacLaury (1992) also suggested that brightness is arguably the most salient dimension in some of languages and later presents a considerable amount of supporting data (MacLaury, 1997a; see also Casson, 1997; Casson & Gardner, 1992). Jameson and D'Andrade (1997) and Dedrick (1997) challenge hue-based theories by suggesting that there is no support for the universal processing of color-opponent unique hues as a cross-cultural basis for category foci and structures. Subsequently, Alvarado and Jameson (2002) and Jameson and Alvarado (2003a, 2003b) empirically show that lightness and saturation lexical mappings agree in Vietnamese and English, whereas hue term mappings do not. From a visual processing standpoint, lightness and saturation sensitivity functions are considered rather uniform dimensions of visual experience (compared to hue experience), even across the wide range of individual observer types that can exist in a population. Thus, despite the subjective distinctiveness of hue, when modeling cross-cultural color-naming universals, the IDM emphasizes lightness and saturation dimensions as a more essential (and more uniformly shared) basis for identifying and classifying stimuli by (a) perceived similarities within categories and for (b) perceived differences across categories. Further discussion and evidence supporting the IDM's emphasis of brightness and saturation are presented by Jameson (in press).

CULTURALLY SPECIFIC INFLUENCES ON COLOR-NAMING SYSTEMS

At least two plausible culturally related sources can have a strong influence on color-naming and categorization systems. These arise from additional culturally salient dimensions beyond those identified earlier and from culturally specific linguistic influences.

The IDM can operate well on dimensions that are strictly defined by culture, such as *freshness* to *dessicatedness* or *loudness* to *quietness*, or even evocative qualities, such as *bold* to *shy* colors. Such culturally prescribed dimensions might intuitively seem less salient or inappropriate to the empirically trained minds of color-naming researchers, but those intuitions in no way undermine the possibility that such dimensions may be legitimate bases for naming and categorizing similarities and differences in other cultures. With regard to these culturally specific influences, the aim of the IDM is to identify which of the possible additional dimensions are most frequently found across cultures. The rationale is that those most frequently seen may then provide insights for systematically characterizing the culturally dependent influences on color naming that are universally seen. Consider again Conklin's (1955, p. 341) Hanunóo example. Hanunóo color designations for which there is "unanimous agreement" include the following:

1. *(ma)bïru* "relative darkness (of shade of color); blackness" (black)
2. *(ma)lagti*ˀ "relative lightness (or tint of color); whiteness" (white)
3. *(ma)rara*ˀ "relative presence of red; redness" (red)
4. *(ma)latuy* "relative presence of light greenness; greenness" (green)

On the face of it, these are easily classified by updates of the Kay, Berlin, Maffi, & Merrifield (1997) theory. However, according to Conklin (1955), this Level I classification "appears to have certain correlates beyond what is usually considered the range of chromatic differentiation, and which are associated with nonlinguistic phenomena in the external environment" (p. 342). That is,

> First, there is the opposition between light and dark, obvious in the contrasted ranges of meaning of [ma] *lagti*ˀ and [ma] *bïru*. Second, there is an opposition between dryness or dessication and wetness or freshness (succulence) in visible components of the natural environment, which are reflected in the terms [ma] *rara*ˀ and [ma] *latuy* respectively. . . . A Third opposition, dividing the two already suggested, is that of deep, unfading, indelible, and hence often more desired material as against pale, weak, faded, bleached, or "colorless" substance, a distinction contrasting *mabïru* and *marara*ˀ with *malagti*ˀ and *malatuy*. (Conklin, 1955, p. 342)

Conklin's (1955) description expresses a clear reliance on the IDM principle of polar opposition in Hanunóo color designations. Also note the central role played by the important sociocultural dimension in Hanunóo color designations, dryness versus wetness.

Another example of a culturally defined dimension exists in the highly developed systems of livestock descriptors. Livestock-specific color terms used by camel breeding and trading tribes in northern and central Saudi Arabia include those from northern Saudi Arabia, such as *waDħaa',* which is a "bright white" color exclusively for camels. (In eastern Saudi Arabia, "bright white" color for camels is *šaqħaa'.*) Also, *saħmaa'* is for speckled light brown camels, and *malħaa'* names speckled black camels. These culturally defined color terms are used in discourse, as are other terms that occur in the lexicon as general color labels, such as *Safraa*' for all things yellow, *bayDaa*' generally for white, *sawdaa'* generally for black, and *ħamraa'* for red.

Similar examples can be given for horses. The suggestion is that color lexicons are in part developed to serve cultural communication needs and thus reflect those needs in content and structure.[10]

Such sociocultural emphases are frequent in the more detailed studies in the literature and illustrate the kinds of principles that the IDM treats as legitimate influences on color-naming systems across cultures. Thus, if information from a given culture dictates that their color space has extra, meaningful dimensions, and if those dimensions seem to be important in differentiating colors, then such dimensions will figure in the IDM analyses of that color-naming system with as much theoretical import as is warranted given the data. If appropriate, such dimensions may take precedence over the salience of intuitively canonical dimensions such as hue, saturation, and brightness.[11] This is not to suggest that hue, saturation, and brightness are likely to be displaced as dimensionally important in otherwise normal observer populations. Rather, it is to suggest that color-naming models should at least permit the possibility that culturally specific dimensions can figure significantly in color lexicon use and development. This fact should be integrated into theories of cross-cultural color-naming systems.

A different source of culturally specific influence is language itself. Kay and Kempton (1984) were among the first to empirically show that judged color similarity varies when a linguistically defined category boundary is available, and Kay and Maffi (1999) discuss such sociocultural influences in the context of color-naming theory. Recently, other investigators have argued that linguistic influences on color-naming systems resemble either general Whorfian-type influence on an individual's conceptualization of color (e.g., Davidoff, Davies, & Roberson, 1999; Dedrick, 1998; Roberson, 2005; Roberson et al., 2000) or as culturally important and meaningful linguistic distinctions, as is argued by Paramei (2005) for Russian blue color terms. Jameson and Alvarado (2003a) also empirically demonstrate the effects of culturally specific linguistic structures on color naming. They suggest that languages (such as Vietnamese) that generally rely heavily on modifier use when naming objects also widely use linguistic constructions of *modifying term plus stem term* when naming colors (Alvarado & Jameson, 2002). Unfortunately, these robust color-naming patterns can be empirically masked due to an "oft used constraint of forced monolexemic naming" (Guest & Van Laar, 2000, p. 731). However, in the absence of empirical constraints, the naming of color in Vietnamese resembles the naming of other classes of things. For this case at least, this shows that linguistic constructions can influence color-naming in ways that produce fundamental differences between the English and Vietnamese color-naming systems (see Alvarado & Jameson, 2002; Jameson & Alvarado, 2003b). Finally, many of the world's languages lack a specific linguistic gloss for the abstract concept we call "color" (e.g., Conklin, 1955, p. 341, n. 12). Lacking a lexical gloss for *color* has obvious consequences for the cultural transmission of a color-naming system between proficient and naïve speakers of a language. One related effect may be a linguistic influence on color category emergence and maintenance (see Jameson, 2005, for a discussion).

THE IDM SUMMARIZED

Four essential IDM premises are as follows: (a) color-naming systems reflect the principled partitioning of color appearance space dimensions, such that the resulting relational structure between category best exemplars maximizes differences between categories and similarities within categories; (b) color category partitions do not simply arise from partitioning a salient hue dimension (contrary to the accepted view of color naming); (c) the priority of brightness and saturation partitions over hue seems, in the absence of other possible influences, most general and universal for describing the development of color lexical codes across all cultures; and (d) influences on dimensional salience arising strictly from culture, language, and environment can also shape evolution of a culture's color lexicon.

As described more generally in Jameson (in press), the IDM explains the prevalence of Berlin and Kay's (1969) basic color categories and also formalizes consequences arising from individual variation. The IDM also accommodates the essential contributions of culture and language that Davidoff et al. (1999) and other moderate cultural relativists actively advance. The notion that color similarity can alternatively be based on perceptual or language-based criteria is compatible with the suggestion that perceptual and linguistic representations are distinct (Dedrick, 1997; Jameson & Alvarado, 2003b; Roberson, Davidoff, & Braisby, 1999).

The remainder of this article provides IDM analyses for composite categories that have generally proved challenging for Berlin and Kay (1969) and colleagues and the view that Hering color-opponent phenomenal channels are necessarily the universal basis for color naming.

COMPOSITE CATEGORY EXAMPLES

MILI AND *MOLA*

How does the IDM further our understanding of *composite categories*? Let's begin with a set of analogies aimed at reexamining the composite category construct and its typical use in color-naming theory. First, consider that according to the Kay and McDaniel (1978, p. 630-31) fuzzy-union definition of *composite* categories, the observed forms of *composite* categories can vary considerably. For example:

> (blue or green) are to the *composite category* GRUE
> as
> (black, green, blue, or brown) are to the Dani's *mili*
> and
> (white, red, yellow, or pink) are to the Dani's *mola*.

In general, however, it seems slightly inappropriate to model the Dani color terms as *composite* categories as Kay and McDaniel (1978) do. Modeling the Dani (Stage I) color lexicon as a system consisting entirely of composite categories—as is any other Stage I language with *warm* and *cool* divisions—appears to complicate Kay and McDaniel's simple *opponent-color* salience explanation. *Mili* and *mola* can be formalized as composites formed by fuzzy unions of the all the “basic” color percepts that a Stage V language reflects, but a system that starts with a warm/cool partition clearly differs in some crucial way from systems based on the theoretical idea of unitary hue-based basic categories. Moreover, to predict on the basis of primary color salience that a Stage I system is on the path to further developing through transitions that represent “the partial or total decomposition of composite categories, with the separate encoding of the primary categories of which they are composed” (Kay & McDaniel, 1978, p. 631), seems like an improper use of hindsight as an inference technique in the modeling of color-naming results.[12]

An alternative way of modeling the data is that the difference between Stage I and Stage V systems occurs simply because different dimensions are emphasized. That is, Stage I systems base naming on partitions along a warm/cool dimension, whereas Stage V systems partition on hue, saturation, and brightness dimensions. This difference in dimensional emphasis became clear in Kay’s (1975) article in which an initial opponent-color black/white division (Kay’s original Figure 2) was updated to properly represent the Dani warm/cool “categories” (rather than “foci”), as depicted here in Figure 6. It can be argued, then, that for cultures operating on warm/cool criteria rather than hue-based criteria, the basis for naming color space partitions is not less developed, compared to a Stage V or VI system—it is simply emphasizing and organizing the lexicon based on a different cognitive construct.

With the one assumption of a difference in dimensional emphasis, the same cognitive principles proposed by the IDM serve to explain both Stage I and Stage V and greater naming systems.[13] Thus, principles of polar opposition-based partitioning with category-area balance, as described earlier, model both sorts of systems equally well. The same cannot be said, however, of a theory based strictly on the universal emergence and lexicalization of six color-opponent primaries (as implied by Kay, 1975, and subsequent revisions). Thus, the only real difference between the initial IDM analysis for English versus Dani is a dimensional emphasis, rather than a strict difference in the conceptualization of the space or in the way the space becomes partitioned once the processing of naming regions is under way. The fact that cultures easily adopt a warm/cool composite partitioning system suggests that, as a basis for categorizing this stimulus domain, warm and cool are alternative organizing properties that are natural to the domain.

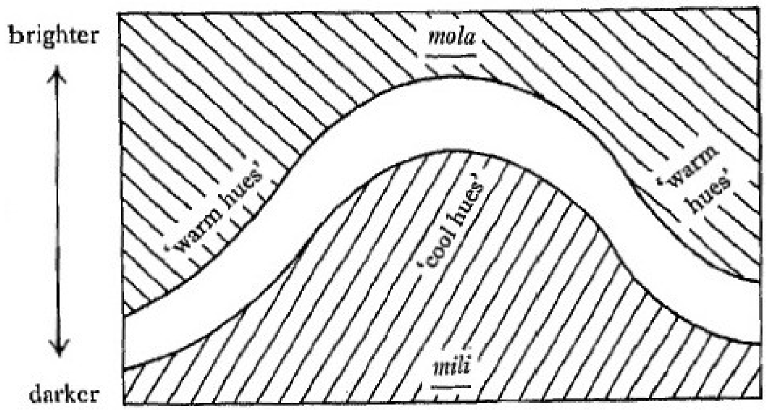

Figure 6: Schematic of Kay's Revised Mapping of the Referents for the Dugum Dani *Mili* and *Mola* Color Terms Onto the Widely Used Mercator Projection Stimulus Grid

SOURCE: Kay (1975, p. 259). Reproduced with permission from Cambridge University Press, copyright 1975.

NOTE: The colors described as *mili* (under the white contour depicted) include some black, green, brown, and blue appearances. The colors described as *mola* (above the white contour depicted) include some white, red, pink, and yellow appearances. See Kay and Regier (2003) for a color version of the Mercator projection stimulus.

Identifying various natural and salient organizing properties, or dimensions, for the space and applying the IDM will yield various forms of naming systems, which may appear different on the surface but will be based on the common cognitive heuristics of the IDM. This is the IDM's approach to explaining the common cognitive universals that underlie color-naming systems that otherwise seem very different.[14]

To summarize, composite categories such as *mili* and *mola* for the Dani (or other Stage I lexicons that exist) are not based on fundamentally different cognitive principles, despite differences in lexicalization when compared to Stage V or VI color-naming systems. However, explanation of Dani naming using a model based on the typical Hering phenomenal opponent colors requires a shift in theoretical emphasis from the usual foci-based explanation (for Stage V lexicons) to a category-based explanation (for Stage I lexicons). The IDM does not require a theoretical shift to explain Stage I or Stage V composite categories because it does not depend, as the formal definition of composite categories does, on an unnecessary assumption of the universal primacy of Hering opponent colors across all language groups.

LOCATING FOCI FOR BLUE AND GREEN, *GRUE*, OR YELLOW-GREEN CATEGORIES

As discussed by Regier and Kay (2004), MacLaury (1997a, pp. 234-235) shows that in Mesoamerican languages, the best examples of GRUE terms tend to fall near green and blue "elementary" foci. As a result, Regier and Kay describe GRUE as a named composite category that consists of two distinct color percepts—one corresponding to appearances glossed by the basic term *blue* and a second corresponding to appearances glossed by the basic term *green* (see also Kay & McDaniel, 1978). Their theory predicts that the foci of GRUE should be bimodal, with some languages showing a GRUE focus corresponding to the "green" focus found across languages that name a "green" region or similarly corresponding to the "blue" focus. Note, however, that in a reanalysis of the World Color Survey (WCS) data, Lindsey and Brown (2004) find that two patterns of GRUE naming can be found in the 110 languages of the WCS. One group places focal GRUE near the typical green category focus *or* near the typical blue category focus, whereas the second group seems to lump blue and green into a single perceptual category and places focal GRUE either near the center of the GRUE area or variously distributed throughout the range (Lindsey & Brown, 2004, p. 293). Thus, focal GRUE may be centered in either blue or green or somewhere in between, making a visual-processing salience argument more problematic. Nor is GRUE the only composite category that strains the usual visual-processing salience arguments, as seen in MacLaury's findings on the yellow-or-green (Y-G) category in Native American languages of the Pacific Northwest (and in the Berinmo, discussed later).

The IDM explains color-naming systems with GRUE or Y-G composite categories in terms of partitions based on alternative dimensional emphases and category-area representation, rather than in terms of the usual best-exemplar focal hue difference emphasis. In explaining a GRUE category, the IDM first emphasizes polar opposites on the dimensions of brightness and saturation, as opposed to strictly on hue. Such an emphasis provides an empirically based rationale for the natural development of GRUE. For example, according to MacLaury's data, elemental hue foci for blue and green within the GRUE category differ primarily in hue and are more similar on lightness and saturation dimensions than the foci for green and yellow elementals, red and yellow elementals, or red and blue elementals (this is expressed in MacLaury, 1997a, p. 87, Axiom 3; MacLaury, 1997b). This high degree of lightness and saturation similarity increases the chance of developing a GRUE category when hue is de-emphasized as a basis for partitioning. Using such alternate emphases, a GRUE category might naturally occur if a labeling system were to lexicalize a category subsequent to a saturation partition (e.g., red) and a lightness partition (e.g., black/white), while simultaneously aiming to maximize the encoding of labels for a domain in which polar opposites light-dark and saturated-desaturated are dimensionally important.[15] A GRUE category that subserves regions of relatively similar saturation and brightness would satisfy both criteria just described and therefore might develop before separate green and blue categories. A GRUE partition simultaneously complements the emphasis of brightness and saturation established by previous partitions *and* spatially balances the partition defined by a saturation category, such as that commonly seen for red. Examination of the Munsell color solid confirms that the GRUE category does balance, to a considerable degree, the dimensional features inherent in a red category partitioned when saturation is emphasized in a naming system.[16]

A GRUE category that is not defined by hue might be expected to exhibit focus variation of the sort described by Lindsey and Brown (2004). Thus, as has been shown, the focus for GRUE in Tarahumara can alternatively favor either green or blue, and the two best examples of green and blue represent the category almost equally well (Burgess, Kempton, & MacLaury, 1983; MacLaury, 1997a). For Tarahumara, an alternating focus for GRUE seems to imply that hue is not an essential attribute of the category area indexed by the GRUE label. Again, principles expressed by the IDM seem most important as determinants of category partitions.

The IDM also explains the relative sizes of category areas for Y-G category observations (e.g., MacLaury, 1997a). In particular, the perceptual scaling analyses of Kuehni (2001) provide useful insights. Using analyses of Munsell perceptual scaling data, Kuehni suggests that there are approximately 1.4 times the number of unit hue differences between unitary green and unitary yellow compared to unitary yellow and unitary red (p. 232).[17] This is important because color-naming research typically assumes a uniform Cartesian metric (in conjunction with orthogonal primary color opponencies) when discussing color appearance spaces (see Jameson, 2005). If, as Kuehni suggests, there is a larger perceptual area subserved by the yellow-green area (in conjunction with the nonorthogonal orientation of the Munsell axes that Kuehni describes), then the IDM predicts that the yellow-green area is of sufficient expanse to earn category status using the principles of category-area balance and distributed category representation. Note that IDM principles that use symmetry and category-area balance operate the same whether a perceptual space has orthogonal or nonorthogonal axes and uniform or nonuniform perceptual spacing.

Thus, GRUE and Y-G categories only present a puzzle when (a) *hue* is put forth as the dominant feature of color category partitions and (b) when the basis for categorization is tied to the notion of four salient unitary hue experiences. When the key emphasis is instead placed on the brightness and saturation dimensions, as central to the unfolding of color category partitions in language, then the IDM dimensional emphasis provides an alternative explanation.

Finally, there are plausible cultural reasons why one language might separately name the components of a composite category (e.g., green and blue) whereas another language does not separately name them (e.g., GRUE). Greater specificity may be needed for sociocultural reasons (i.e., dye industry developments) or arise due to properties of the language (i.e., increased modifier use), which make uncoupling GRUE unnecessary. For example, grue-like-the-ocean, and grue-like-the-leaves are perfectly normal meaning units and are syntactically compatible with linguistic construction in the languages in which they are found. Even pragmatic reasons can make uncoupling GRUE unnecessary (as exemplified in the Berinmo data discussed below).

I believe there are problems inherent to seeking uniform agreement in the placement of foci for color categories. As Lindsey and Brown (2004, p. 292) report, even *within a given language,* there is considerable variability across speakers in the uniform usage of categories such as blue, green, GRUE, or dark.[18] Indeed, even if we hypothesize a best-case scenario, in which there is certainty that a specific group of native speakers all share the same abstract internal representation—identical internal qualia—for an imagined unitary green experience, it still would be unlikely that all speakers would match their internal qualia to the same physical color sample. The many sources of variability in each individual's visual processing system (i.e., differences in lens yellowing, photopigment density and sensitivity, macular density, etc.) would always result in individual behavioral differences when matching identical shared internal qualia of green to green samples in the world. Such problems with foci determination for GRUE apply to all color categories. However, fixing absolute foci is not an obstacle for the IDM characterization of color naming because category best exemplars are expected to *float* as categories emerge and redistribute members (Jameson, in press). This difference in emphasis of floating versus fixed focal exemplars is another advantage of the IDM's alternative explanations for understanding color category–naming relations. See the section below and Jameson (in press) for examples of *floating* best exemplars.

BERINMO "COMPOSITE" CATEGORIES *NOL* (BLUE-GREEN) AND *WOR* (YELLOW-GREEN)

Recent research makes a strong case for linguistically influenced color naming (Davidoff et al., 1999; Roberson et al., 2000; Roberson, 2005). These investigators raise questions about the universality of Berlin and Kay's (1969) *Basic Color Terms*. Their research identifies cases in which the 11 basic terms are not supported (in an ordered or unordered sequence). For example, Roberson et al. argue that invariance of response is strongly associated with language structure. They emphasize a need for research to acknowledge linguistic relativity in color naming. They further suggest that linguistic structure and language processing are not properly considered in the widely accepted Berlin and Kay formulation and are indeed a large component (if not the main component) affecting color-naming systems cross-culturally.

Davidoff et al. (1999) and Roberson et al. (2000) dispute Kay et al.'s (1997) suggestion that Berinmo is a five-color category system:

> A similar oversimplified picture arises using the Kay et al. classification for Berinmo. The Berinmo *wor* category encompasses some green; the *nol* category encompasses much of green, blue, and blue-purple; *wap* covers almost all of the lightest colors at lightness 9/ on the Munsell scale and some of those at lightness 8/ including focal pink; and *kel* covers almost all dark colors at Munsell lightness 2/, many at lightness 3/ and many purples up to lightness 6/. So to suggest that the Berinmo have the equivalent of five English categories seems uninformative. (Roberson et al., 2000, p. 377)

Thus, unlike the range spanned by English color category exemplars, "hue" is not always uniform within the categories Berinmo name, making Berinmo a color-naming system with what could be described by English standards as five "composite categories."

Figures 7 and 8 illustrate the mappings of English and Berinmo color naming from the Roberson et al. (2000) stimulus array.

Investigating Berinmo category foci, Davidoff et al. (1999) found that in Berinmo, green and blue are grouped under a GRUE category called *nol,* with a focus very near a green focal. Figure 1 from Davidoff et al. also reveals that the regions mapped by English blue and green categories are similar with respect to saturation (6.7 vs. 7.3 average chroma, respectively) and lightness (5.57 vs. 5.18 value, respectively). Compared to the English categories, the observed Berinmo *nol* category seems, on average,

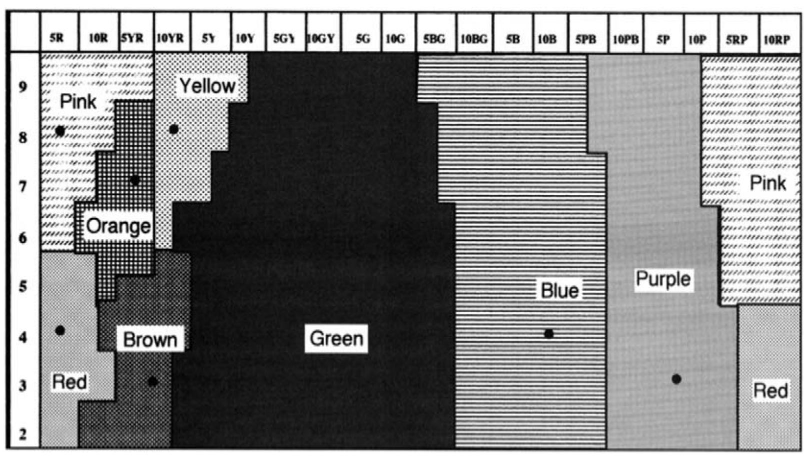

Figure 7: Achromatic Figure Depicting English Naming and Choices of Best Exemplars for a 160-Chip Saturated Array Showing Focal Points for Each Color Category as Reported by Rosch Heider (1972)

SOURCE: Figure adapted and modified with permission from the American Psychological Association, Inc.

NOTE: Although represented in gray scale here, Rosch's stimuli were Munsell color chips of glossy finish and are referred to by their Munsell notations. The array consisted of hue Levels 5 and 10 of 10 evenly spaced steps around the Munsell hue circle. As described by Kay (2005), this 160-cell hue/lightness array omits every other hue column of the 320-cell hue/lightness Mercator projection array widely used by Kay and colleagues in the World Color Survey (see Regier & Kay, 2004).

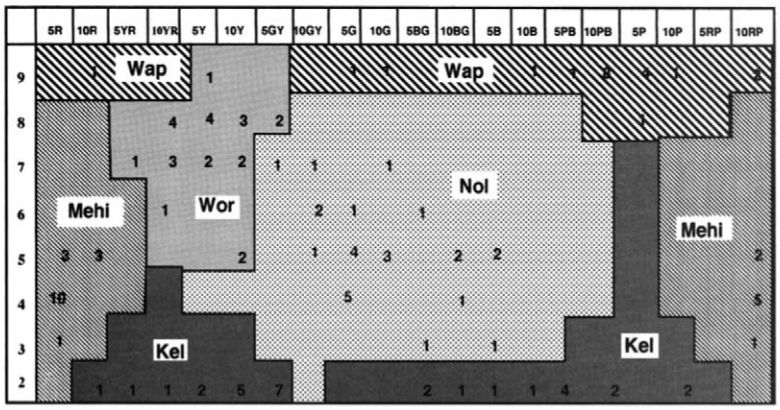

Figure 8: Achromatic Figure Depicting Berinmo Naming and Choices of Best Exemplars for a 160-Chip Saturated Array for 25 Participants

SOURCE: Adapted and modified with permission from the American Psychological Association, Inc.

NOTE: As in Figure 7, the 160-cell hue/lightness array uses every other hue column of the 320-cell hue/lightness array widely used by Kay and colleagues in the World Color Survey (see Regier & Kay, 2004). According to Roberson et al. (2000), their stimulus materials were identical to those used by Rosch Heider (1972), as described in the caption for Figure 7.

more saturated (average chroma = 7.96), with similar average lightness (i.e., 5.26). If these trends were substantial enough, this might be interpreted as a comparative similarity between Berinmo and English bluegreen category structure with respect to lightness but a comparative difference with respect to saturation and hue.

The Davidoff et al. (1999) and Roberson et al. (2000) mappings of Berinmo naming show that the term *wor,* which is a yellow-green *composite* category, covers a good deal more category area than does the English yellow category.

According to the IDM, there are two possible routes by which the IDM would permit the "emergence" of *nol* and *wor* as found in Berinmo. The first route is compatible with Figure 1 (Kay's 1975 model) but only as far as Stage III of the sequence. That is, the GRUE *nol* category of the Berinmo could have emerged after *mehi* (or red), consistent with Figure 1, but the emergence of a yellow-green *wor* as Stage IV requires a revision of the model to allow for a yellow-green option at Stages III and IV. Kay et al.

(1997) aimed to add systems containing yellow-green composites to their theory but note that "extension of the model to yellow-green systems requires us to add significant complexity of an *ad hoc* kind to cover a small amount of data. Yellow-green systems remain an area that needs careful additional work" (p. 32). In contrast, allowing *wor* as Step IV is permitted by two IDM principles: (a) category symmetry and polar complementarity on the lightness dimension because *wor* exemplars tend to be lighter relative to *nol* exemplars, and (b) the next natural lexical specification of a considerable range of unnamed color space after Step III could be a *wor* partition. It should be noted that the converse sequence in which *wor* emerges at Stage III and *nol* at Stage IV would be equally justified on the basis of these IDM principles.

However, in Berinmo, there are additional cultural factors likely to influence the emergence of *wor* and *nol,* as described in the following statement of Roberson (2005):

> For Berinmo speakers, . . . tulip leaves, a favorite vegetable, are bright green when freshly picked and good to eat, but quickly yellow if kept. Agreement over the color term boundary coincides with agreement over when they are no longer good to eat and is highly salient in a community that talks little about color. (p. 66)

In this case, the salient dimension is a culturally and pragmatically defined gradient from a *good-to-eat green* to a *less-appetizing yellow*. Trading off such cognitive and cultural dimensions (while preserving IDM principles), the existence of *wor* and *nol* in Berinmo color naming becomes much less problematic.

In general, the IDM's core cognitive partitioning principles do not predict uniform naming of a discontinuous color category such as Berinmo's *kel,* as seen in Figure 8. When such a result is observed, its basis should be explored to rule out the possibility that discontinuities arose due to stimulus sampling, choice behavior set effects, or other empirical events. Note that the IDM permits compelling cultural influences to produce uniform lexicalization of discontinuous category regions. However, the IDM predicts that when discontinuities are idiosyncratic in ways that render the information code ineffective, those representational discontinuities will be inconsistently used and, with time, will not be maintained as part of the color-naming information code.

Lindsey and Brown (2004) suggest that individual variation in color naming is a serious obstacle for theories based on linguistic relativity (i.e., Davidoff et al., 1999). From the IDM's perspective, a high degree of uniformity in category naming within an ethnolinguistic society that communicates via a shared language and a shared set of values would not be expected given the effects of plausible linguistic influences and communication pragmatics on naming. To address this, the IDM adopts a principle called *linguistic charity* (Putnam, 1988), which is a feature of human communication used to disambiguate meaning. This principle suggests that color category names are not deterministically linked to specific appearances. Within a society, individuals will vary in their mastery of the color-naming function. This is expected and is handled by flexible mapping of the lexicon, as occurs in many meaning systems seen in language (see Jameson, in press; Jameson & Alvarado, 2003b). Formulated in this way, the individual variation in color naming that Lindsey and Brown describe may in part be a function of the normal flexibility of label-to-exemplar mapping seen throughout languages.

These Berinmo examples support the idea that for composite categories (e.g., GRUE and Y-G), the brightness dimension is important, whereas hue is less important. This kind of analysis can be extended to yellow-green-blue categories as well as the "cool" black-green-blue categories that have been observed in the literature. MacLaury (1992) previously emphasized the importance of the lightness or brightness dimension in explaining yellow-green-blue partitions seen in his data, and I believe that this emphasis should be further developed in color-naming theory.

RUSSIAN LANGUAGE COLOR TERMS GLOSSING *BLUE*: *SINIJ* AND *GOLUBOJ*

The IDM predicts that the order of successive category partitions should aim to maximize distinctiveness first on the basis of brightness, second on saturation (when brightness differences are minor among the choices available), and third on hue (when the differences on the preceding two dimensions are less than the hue differences), followed by a return to brightness and saturation differences when hue differences have become comparatively trivial through subdivision. For example, English *pink, peach,* and *salmon* gloss lightness and saturation partitions within a reddish category region, which occurs in the sequence after comparably sized partitions have been established largely on the basis of hue differences. See Boynton (1997) for related comments on the emergence of "basic" *peach* in English. This successive partitioning can continue as long as maximizing the perceived difference between lexically encoded categories optimizes the accuracy of the lexical code. The result is that the encoded concepts are distinct and general and carry relatively unambiguous semantic values. When two or more lexical items maximize the interpoint distance relations between centrally encoded exemplars, this improves the likelihood that semantic confusions will be reduced when speakers of the language converse about color.

An important illustration of this process and its role in composite categories can be seen if we consider Russian color naming and categorization. It has been well documented that the Russian language has two color terms to describe "blue" appearances. These qualify in almost every way as having *basic* status in the language (e.g., Corbett & Morgan, 1988; Morgan & Corbett, 1989). As discussed by Paramei (2005), these two basic terms—*goluboj* for a light blue and *sinij* for a darker blue—present a modeling challenge for understanding the construct of color category *basicness* as well as for defining the idea of category focal appearance. It seems likely that if basic color term theory had originated in native-language-speaking Russia, the initial hierarchy might have been formulated to accommodate *two* basic color terms for the blue category rather than only one. From the native-language Russian point of view, then, the English category glossed by *blue* would be a *composite* category because the English color space partition glossed as *blue* combines *sinij* (dark blue) or *goluboj* (light blue) exemplars. Conceptualized in this way, the Russian "blue" category structure presents an interesting opportunity to test whether the IDM can explain how composite categories generally develop when the composites are not defined by the usual fuzzy unions of two primary colors. This only requires the sensible assumption that what defines a composite category can be any two sources of salience, as opposed to composites formed solely by the Hering principle hues as usually construed.

As Paramei (2005) suggests, IDM partitioning principles applied to the considerable expanse of the category glossed by English *blue* provide nonlinguistic grounds for the refinement of the blue category in Russian. Paramei argues that "the 'Interpoint-Distance Model' (IDM) suggests that the emergence of goluboj follows from a natural partitioning of the considerable gap of unnamed colors between basic 'blue' and 'white'—one of its longest unpartitioned stretches of perceptual color space" (p. 27-28). This provides the *necessary* requirement for the emergence of *goluboj*—the Russian light-blue category term (G. Paramei, communication, May 2004). Secondarily, sociocultural influences provide further justification for the emergence of Russian *goluboj* as distinct from *sinij*. Paramei states,

> The idea is that differentiation [between *sinij* and *goluboj*] is encouraged and reinforced by the culture to which native speakers belong, such that speakers encounter special conditions that make certain color differences which may otherwise be nonsignificant, crucial and behaviorally important (Frumkina, 1999). . . . [Frumkina also] argues that *goluboj* should be considered culturally basic for Russian, because Russians cannot designate blue eye color and the common color of sky without this term. (p. 29)

Figures 9 through 12 illustrate the process by which the IDM principles anticipate *goluboj* emerging in the context of an existing

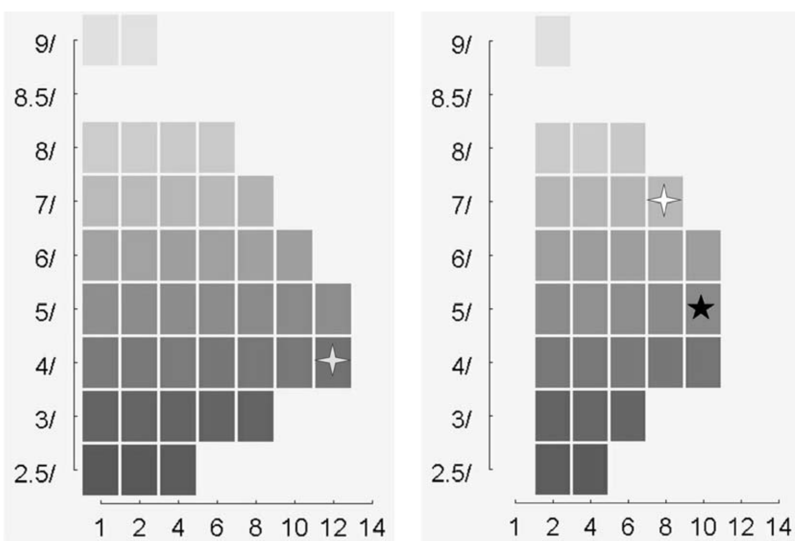

Figure 9: Grey-scale Renderings of Munsell Constant Hue, Pages 5PB (on left) and 2.5PB (on right)

NOTE: *Munsell Book of Color* (1976) pages were created using CVD.exe software (Irtel, 1992) publicly available for download at http://www.uni-mannheim.de/fakul/psycho/irtel/cvd.html.

sinij category. First, Figure 9 illustrates hue pages 5PB and 2.5PB from the *Munsell Book of Color* (1976). The left-hand hue page of Figure 9 depicts a four-pointed star at the position empirically determined as the best-exemplar focus for *sinij* (i.e., Munsell notation 5PB 4/12). On the right-hand side, Figure 9 depicts a four-pointed star denoting empirically determined *goluboj* (i.e., Munsell notation 2.5PB 7/8). Both *sinij* and *goluboj* foci depicted are based on the data of Frumkina (1984), as reported by Paramei (2005, Figure 2). In addition, Figure 9 depicts a black five-pointed star denoting MacLaury's (1997b) WCS "elementary blue" focus. MacLaury designates "elementary blue" (i.e., the blue sample that, across cultures, is most often named with a *blue* gloss) as Munsell 2.5PB, value = 5, chroma = 12.

Figure 10 allows for appreciation of the considerable color term specificity imposed by English speakers on the range of Munsell stimuli depicted in Figure 9 (i.e., *Munsell Book of Color* [1976] pages ranging from hue page 9B through 5PB). Together, Figures 9 and 10 illustrate that (a) a range of perceptually different samples comprise the English blue category; (b) MacLaury's (1997b) "elementary blue" analysis shows that from among these samples, many English speakers (and speakers of other languages) can, to some extent, agree on the best exemplar of that perceptual category; and (c) in English, such ranges of samples can be lexically specified (either by using modifying terms on the stem term *blue* or by finding other monolexemic stem terms such as *ultramarine*).

In contrast to English color naming of the blue category just described, Figure 11 illustrates how Russian lexicalizes the blue category. Figure 11 depicts a grayscale schematic drawing of the Munsell color solid with the locations of empirically defined *sinij* and *goluboj* foci reported by Frumkina, 1984, as seen in Paramei's [2005] Figure 2) relative to MacLaury's "elementary blue" location.

In Figure 11, the horizontal gray plane represents the hue circle (depicted earlier in Figure 2) at Munsell midlightness level (value = 5). The vertical axis is the Munsell value, or the lightness axis, ranging from white at the top and black at the bottom (as seen in Figure 3 earlier). The vertical semi-cylindrical surface represents a grid of constant Munsell saturation (chroma = 5) within the space. On the plane of the hue circle, horizontal radial lines labeled *2.5PB, 5PB,* and *7.5PB* represent lines for three specific constant hue pages from the *Munsell Book of Color* (1976; see Figure 3's schematic and Figure 9's example hue pages). Along these constant hue lines, locations near the horizontal-vertical

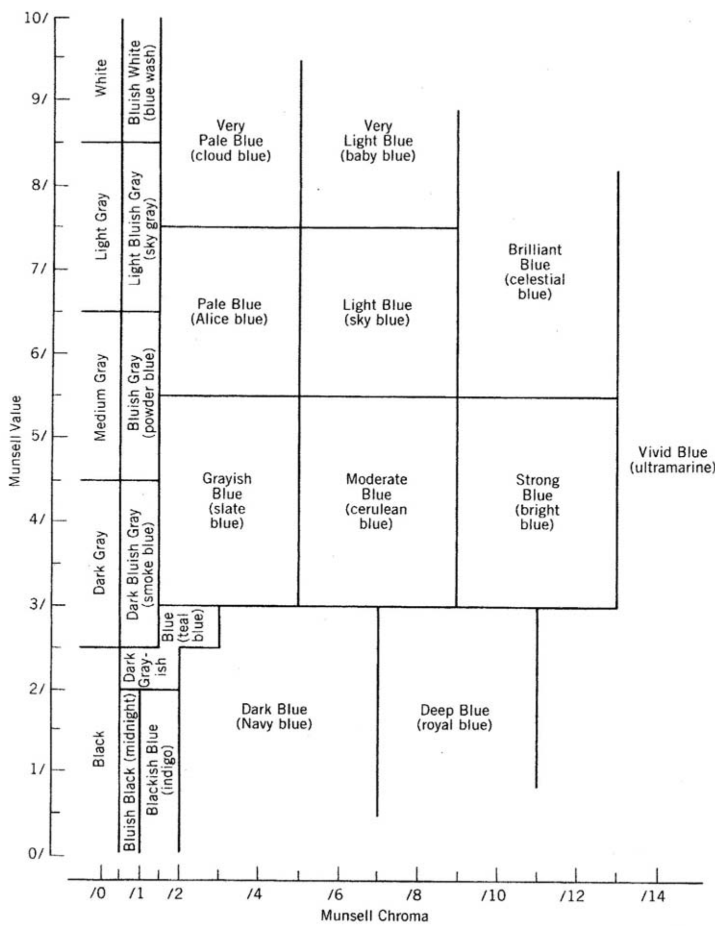

Figure 10: Names Assigned to Colors at Various Munsell Values and Chromas for the Range of Munsell Hue Pages Between 9B and 5PB

SOURCE: Adapted from Billmeyer and Saltzman (1981, p. 33) with permission from John Wiley. Originally reproduced and modified by Billmeyer and Saltzman from Kelly and Judd (1976).

origin are very desaturated (i.e., lacking color depth), whereas locations close to the edge of the hue circle are the most highly saturated (i.e., deep color). At the end of radial line 2.5B, the black five-pointed star represents the location of the Munsell chip that MacLaury (1997b) designates as "elementary blue," or the blue

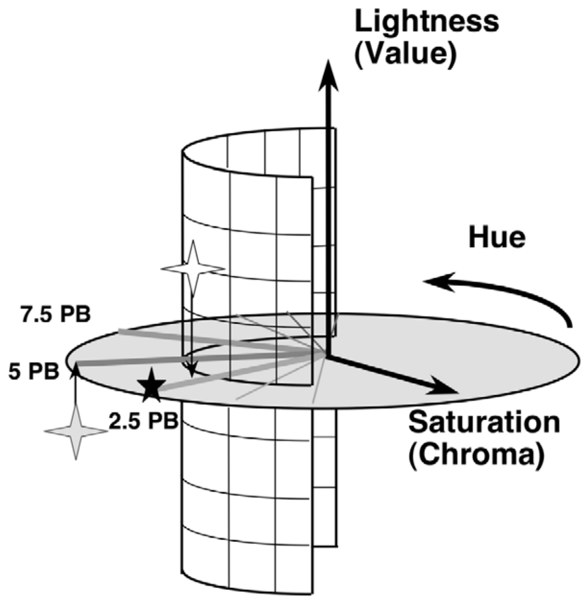

Figure 11: Empirically Determined Locations of Focal *Sinij* and *Goluboj* Positioned in a Schematic of the Munsell System

NOTE: Foci reported by Frumkina (1984), as discussed in Paramei (2005, p. 17). Horizontal radial lines labeled *2.5PB, 5PB,* and *7.5B* represent lines for three specific constant hue pages from the *Munsell Book of Color* (1976; see Figures 3 and 9). The black five-pointed star on radial line *2.5PB* represents the location of the Munsell chip that MacLaury (1997b) designates as "elementary blue" (i.e., Munsell 2.5PB, value = 5, chroma = 12). The four-pointed star above the hue plane and nearest to the grid of constant saturation represents *goluboj's* empirically determined location (i.e., 2.5PB at value = 7 and chroma = 8). The four-pointed star *beneath the hue plane* represents the empirically determined location of *sinij* (i.e., 5PB at value = 4 and chroma = 12).

sample that across cultures is most often named with a *blue* gloss (i.e., Munsell 2.5PB, value = 5, chroma = 12). On the same hue, line 2.5PB is where Frumkina's (1984) empirically determined location of *goluboj* is found (i.e., 2.5PB at value = 7 and chroma = 8). *Goluboj's* location is denoted by the four-pointed star above the horizontal uniform lightness plane (i.e., value = 5) and outside the curved grid of constant saturation (i.e., chroma = 5). Thus, *goluboj* is a rather light and saturated blue Munsell sample. Considering the adjacent radial hue line labeled 5PB, *sinij* is represented as the shaded four-pointed star *beneath the horizontal* *plane* (i.e., Fumkina empirically determined *sinij* as 5PB at value = 4 and chroma = 12). By comparison, *sinij* is in a position of the color space relatively darker than both *goluboj* and "elementary blue" and more colorful, or saturated, compared to *goluboj*.

SINIJ AND GOLUBOJ AS "BASIC" COLOR TERMS

Figure 11 illustrates that *sinij* and *goluboj* both coexist as "basic" blue category color terms, in part due to a separation consistent with the IDM polarity principle on lightness and saturation differences.[19] Figure 11 shows that the location of MacLaury's (1997b) "elementary blue" occurs at a mid-lightness level (Munsell value = 5) and central to the bluish region of the Munsell Mercator projection (as seen in Hardin, 2005, Figure 3b). By comparison, Russian's *sinij* is a lexical referent for the large expanse of the blue region offset from MacLaury's "elementary blue" focus and is denotatively "decentralized," as shown in Figure 11. As a result, the emergence of a complementary *goluboj* is expected because *goluboj* effectively balances *sinij*'s lightness and saturation features and provides for needed representational specificity in the blue region. Figure 11 illustrates that the informational load inherent in lexicalization of the blue region is distributed and shared across the two Russian blue terms, whereas in English, a single term carries the entire denotative burden and is accordingly focused more central to the blue region.

Note that both MacLaury's (1997b) and Frumkina's (1984) blue foci were obtained using the Mercator projection stimulus typical of much color-naming research (e.g., Kay, 2005). In using such a stimulus, one cannot exclude the possibility that the empirically identified locations for "elementary blue," *sinij,* and *goluboj* foci are largely a consequence of that Mercator projection of the Munsell solid "skin" as the stimulus array to identify those foci. Because Munsell chroma is maximized in that stimulus, variation that might otherwise be seen in the saturation component of the WCS "elementary blue" remains unspecified because subjects were forced to simultaneously trade off lightness and saturation by choosing from fixed value and chroma combinations in which chroma was always maximized. Thus, when selecting foci, subjects were not allowed to identify a given lightness level independent from a saturation level, and saturation was always constrained to the most saturated chroma level achieved by the

Munsell hue pages. There is no question that saturation variation plays an important role in differentiating “basic” color foci. For example, in English, the focus for *pink* generally differs from the *red* focus by a relative increase in white, desaturating pigment and an increase in lightness. If a stimulus were used in which saturation were also allowed to vary independent of lightness, then, consistent with IDM theory, even greater separation along a saturation continuum might be seen for empirically determined *sinij* and *goluboj* “basic” foci.

Despite this saturation variation limitation, the locations of *sinij* and *goluboj* foci depicted in Figure 11 exemplify the two IDM principles discussed earlier. That is, considering the range and extent of blue pages present in the *Munsell Book of Color* (1976), the foci for *sinij* and *goluboj* suggest a polar optimization of best-exemplar relational structure on both a *lightness continuum* and a *saturation continuum*. The two foci are well distributed and separated on the Munsell value axis while simultaneously being separated and distributed on the chroma axis (by four chroma steps).[20] Their relative positions tend to optimize best-exemplar separation while maintaining a position representative of the blue pages of this stimulus space (i.e., sufficiently distant from blue category boundaries) and sharing the informational load across the two terms. These features of Russian’s *sinij* and *goluboj* give confidence that the two category terms behave as two basic color terms might behave in the Kay et al. (1997) sense. Note that the extent of the stimulus space determines category-area size and thus boundary locations and relative interpoint structural relations. (Size-relative dependence can be appreciated by comparing the different possible IDM mappings seen in Figures 11 and 12, discussed below.) However, the dynamics inherent in the described IDM modeling apply regardless of changes in stimulus space extent, and the IDM principles described predict category partitioning and labeling of any size stimulus domain regardless of the coarseness of the sampled stimulus set.

ILLUSTRATING THE EMERGENCE OF GOLUBOJ

The IDM partitioning of blue for the Russian categories *sinij* and *goluboj* might unfold as follows. Imagine a point in time when a form of Old Russian developed its color lexicon hierarchy to obtain Stage V (see Figure 1). Assume that the Russian blue term at that point was a precursor of *sinij* and that for historical or cultural reasons, the best exemplar of that precursor of the *sinij* (or proto-*sinij*) category was biased toward the dark and midsaturated portions of the color space. Consider that such a proto-*sinij* would leave a large expanse of the blue region unnamed, and suppose that some significant need arose to describe appearances from that unnamed blue region. With a dark, midsaturated proto-*sinij* already in place (for purely illustrative purposes, let's say in the region surrounding row 30 and column 30 of Figure 12), the optimal choice from an information representation standpoint is to define a polar-opposite complement for the dark, midsaturated proto-*sinij* as formed by a new category *goluboj* (e.g., row 70 and column 60 of Figure 12).[21] *Goluboj* thus defined follows from an IDM partition along the vertical lightness dimension of Figure 12, producing a light-dark partition of the color region, combined with a partitioning to differentiate chromatic appearances from achromatic appearances (along the gradient dimension of horizontal "saturation" or purity in Figure 12). The IDM permits these lightness and saturation partitions to occur either simultaneously or as separate events.

For the case of Russian blue, then, the IDM partitioning of the blue region could produce two distinctly named color categories within Figure 12's hue page, which finely samples from lightness and saturation continua. Note that by partitioning *goluboj* as described, the best-exemplar focus region of the hypothesized proto-*sinij* should, according to IDM theory, shift to regularize interpoint separation among the foci represented by category partitions, similar to the "floating foci" notion expressed in the literature (see MacLaury, 1997a, p. 25). Thus, the best exemplar of modern-day *sinij* would be predicted as slightly shifted from the proto-*sinij* that is hypothetically placed at row 30 and column 30 in our Figure 12 example.[22] This shifting best-exemplar property is, in this example, due entirely to *goluboj*'s emergence and the need to regularize the relational structure between this new *goluboj* best exemplar and the proto-*sinij* best exemplar. Exactly where the proto-*sinij* best exemplar historically occurred in color space is a detail that may be difficult to determine. However, Figure 12 does illustrate the IDM perspective that color category foci are expected to spatially shift as new categories are introduced into the lexicon and that this dynamic aspect of best-exemplar location is also shaped by IDM principles that optimize the information code for color categories in the lexicon. Moreover,

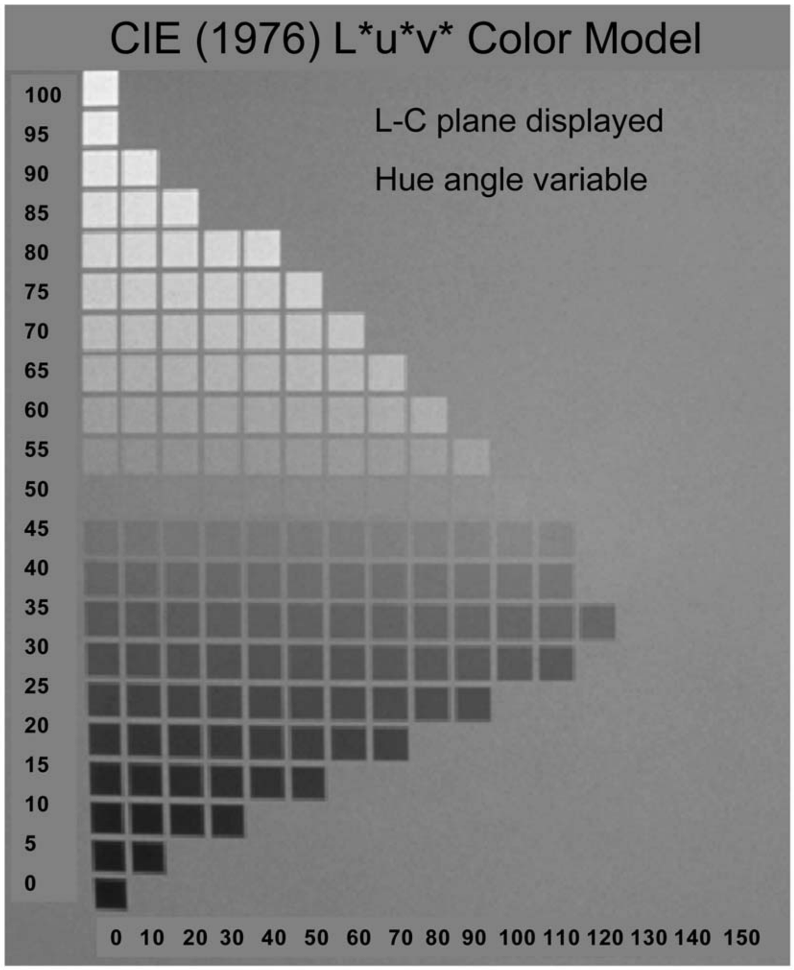

Figure 12: Constant Hue Page in CIE L*u*v* Color Space Rendered by a Standard Gamut Permitted by Monitor Phosphors

SOURCE: Image credit: *Colour in Computer Graphics Photo CD*. MacColour Limited, copyright 1996 (http://www.agocg.ac.uk/gv/issue52/colour.htm).

by comparing blue category lexicalization under the considerably different blue region representations of Figures 9 and 12, it becomes obvious that the properties and extent of the color space employed can influence the interpretation of color category denotative regions. In particular, if a space with limited variation on a given dimension is used, then actual category distinctions based on such variation may not be apparent despite the fact that it might actually play an important role in color category lexicalizations and distinctions.

HISTORICAL ANALYSIS CONSIDERATIONS IN THE MODELING OF COMPOSITE CATEGORIES

Historical analysis is important to the modeling of composite category naming. This is true especially of color lexicons that are classed as being in the early stages of Berlin and Kay's (1969) and colleagues' hierarchy of color term emergence. It is certain that Kay and colleagues are sensitive to such issues, as seen above in the quote regarding Japanese *ao* (also see Kay, 1975), but typically, historical considerations do not play a role in investigations of contemporary color lexicons and are not easily incorporated in color cognition and naming models. Historical development of a lexicon is, however, central to theorizing about the path by which *composite* and *basic* color categories develop because, as defined by Kay et al. (1997), a color lexicon cannot express *Basic Color Terms* without first passing through several stages in which basic terms are grouped together under composite labels. Yet, theory on the emergence of color lexicons and theory about features driving individual color naming are often not distinguished in ways that help separately clarify these different phenomena (cf. Boster, 1986). This can make it difficult to determine whether "composites" arise as a function of a stage designation, due to psychological processing features, or from a combination of both. In fact, because even contemporary lexicons remain dynamic, it may be that discovering that a language has a robust *composite* category reveals more about the historical timeframe of the language studied than it does about individual psychological processing features actually driving lexicalization of the stimulus domain.

Three composite category analysis examples serve to briefly illustrate how historical considerations can be difficult to disentangle from other color category influences.

First, suppose a given contemporary color lexicon is analyzed at the historical step just after a composite GRUE partition is named. By IDM theory and by empirical experience, there is reason to expect development of subsequent lexical partitions based on lightness, saturation, and hue. But in diachronic analyses of still-developing lexicons, we know that the lexical expression of those potentially important psychological distinctions might be missed. Thus, it is difficult to determine if the absence of a subpartitioned GRUE region is due to cognitive representation differences or to the historical timeframe examined.

Second, in retrospective historical analyses, alternative "emergence" paths may be easily overshadowed and overlooked. For example, because new hue terms may be easily borrowed from other languages or developed through social interaction, the origin of a term in a lexicon can be difficult to pinpoint. Specifically, consider English *blue,* for which there is varying ideas regarding its origin. One idea is that *blue* emerged pragmatically through the use of a vegetable dye made of woad by 6th-century Celts and became more prominent in the dye industry beginning in the 12th century (Pastoureau, 2001). *Blue* emerging in this recent pragmatic way suggests uncertainty concerning whether the "hierarchy" of English color terms came to us strictly ordered—with *blue* emerging with the other "landmark colors," before the secondary color terms—according to the Berlin and Kay (1969) sequence (e.g., Bk, Wht, R, G/Y, B, Brwn, Pur/Pk/O/Gry). Another suggestion is that English words for blue appearances were inherited by way of Latin's undifferentiated blue-green-black category and then subdivided and labeled using borrowed terms from precursors of German and Arabic (Pastoureau, 2001).[23] This latter idea supports the earlier IDM assertion that hue can differentiate categories at different stages of development after lightness and saturation dimensions are emphasized, but again in this example, we note different possible sources driving color term emergence and also an indirect path to the usual "landmark colors" sequence, both dependent on the accuracy of quite old historical accounts or data.

Third, Johnson, Johnson, and Baksh (1986) described results for the Machiguenga (southeastern Peru) Stage V color lexicon, which possessed separate terms for green and blue, plus a separate term for GRUE. This Machiguenga example illustrates how salient cognitive emphasizes might produce and maintain a brightness and saturation partition of GRUE, with a subsequent partition based on hue differences (green vs. blue). This is speculation, however, because Johnson et al. do not investigate the psychological dimensions used and shed no light on the order of the development of the three lexical categories, and one cannot know which came first, the GRUE or the green and blue categories.

These examples illustrate that several color term emergence paths are possible for designating blue and green, but the impetus for different paths may arise from different sources (e.g., a pragmatic source in the dye use case, a social source in the term-borrowing case, and perhaps both psychological and cultural sources in the Machiguenga example). More important, however, these different paths—and the different sources driving them—are not equally assessable when analyses rely largely on incomplete or unverifiable historical data. For this reason alone, comparing individual cognitive categorization processes or behaviors with color lexicon emergence seems likely to diminish the chance for a clear understanding of either.

Ultimately, these examples underscore the idea that it can be difficult to show whether, over the course of a color lexicon's development, the contemporary endpoint we observe today clearly followed a linear-ordered sequence of color term emergence that could be postulated as an "evolutionary sequence." Despite this difficulty in modeling color lexicon "emergence," modeling the cognitive representation of a *contemporary* color lexicon, irrespective of a lexicon's stage designation, reveals a good deal about the relations between a speaker's denotative color term meanings and their psychological sense of color similarity. Thus, perhaps the best way to model the progressive development of a color lexicon is to specify the properties that generally shape and justify the naming and partitioning of color space using language and to track the interplay between cognitive and cultural factors in the languages as they can still be observed or documented.

CONCLUSIONS

An alternative perspective for color categorization and naming can be used to characterize the composite categories found in many languages. This alternative perspective proposes that there are good reasons to consider cognitively and culturally defined dimensions as appropriate "universal" features on which the lexicalization of color appearance space can occur. This alternative perspective is called the *Interpoint-Distance Model* to emphasize that optimization of the relational structure among category best exemplars is an important factor in the emergence of color category partitions. The model de-emphasizes the usual practice of establishing specific category *foci,* in contrast to prototype exemplar-based modeling approaches, and instead uses a cognitively based heuristic approach to explain how color categories are named across cultures. With respect to Dedrick's (2005 [this issue]) analysis of color-naming research explanations, the IDM more closely resembles a probabilistic "robust process explanation" than it does an "actual sequence explanation" more closely linked to causal determinism. Note also that the *composite* category analyses given above all relied heavily (if not exclusively) on brightness and saturation dimensions. This is in part because, as formalized in the literature, *composite* categories are by definition nonhomogeneous with respect to hue. This definitional feature of nonhomogeneity with respect to hue seems to imply that differences along a hue dimension would not serve as an adequate basis for modeling or predicting the naming of composite categories. Thus, in this respect, the theoretical bases for basic and composite categories also seem to differ. Other examples provided here exemplify that atypical dimensions play important formative roles in the color naming (e.g., a dimension of dessicated-to-supple occurs for Hanunóo color categories, as well as a dimension of *good-to-eat green* to a *less-appetizing yellow* for the Berinmo). These show that the IDM does make use of dimensional analyses beyond the brightness and saturation examples described here.

The following principles are proposed in the present IDM analysis of *composite* categories:

I. The cognitive dimensions (ordered by importance)—brightness, saturation, and hue—are primitives in cultural color representations. However, brightness and saturation are of paramount importance in the initial stages of a culture's color naming of composites.

II. Composite color categories develop through successive partitioning of color appearance space on the basis of the dimensions given in Principle I above. The resulting category partitions strive to satisfy two equally important goals: (a) optimization of polar symmetry and category-area uniformity and balance relative to the cognitive dimensions listed in Principle I and (b) responsiveness to sociocultural demands for representational specificity of color, as well as compatibility with existing ethnolinguistic structures.

The implementation of Principles I and II results in a relational structure among categories that is effective for the communication needs of the users of the color-naming system. The following consequences arise from these enumerated principles of the IDM:

1. Because the constraints of Principles I and II are universal across cultures, the evolution of color-naming systems will converge somewhat, producing general features of color naming that are universal across cultures (Jameson, in press).
2. Although category partitions manifest by following the principles stated in Principle I, they may also undergo successive repartitioning in response to social pressures, such as a novel need to differentiate blue and green separately from a previously defined GRUE category.
3. When differentiation on the basis of lightness and saturation has been optimized, the IDM permits successive repartitioning to occur using goals emphasized in Principle II, which could be based on distinctions along the hue dimension, thereby partitioning even further the "composite" region of the space by color category lexicalization.

NOTES

1. Although Kay and Maffi (1999) more recently disavow the specific neurophysiological linkage that Kay and McDaniel (1978) developed, the linkage between some "focals" and color percepts typically tied to Hering's six opponent primaries continues to be maintained in the theory (e.g., Kay & Regier, 2003). Kay now identifies these constraints on color naming as based on presumed universals of color appearance—that is, opponent red/green and yellow/blue *phenomenal channels* (Kay, 2005). Nevertheless, recent cross-cultural color categorization research often maintains the original link between the revised Kay, Berlin, Maffi, and Merrifield (1997) theory of naming and specific physiological processing channels, apparently without much controversy (e.g., Guest & Van Laar, 2000; Hardin, 2005; Lin, Luo, MacDonald, & Tarrant, 2001a, 2001b).

2. Kay (1975) also tentatively developed further changes to address the then "remote" possibility of a yellow-green composite category in some languages and continued to enrich the theory further by extending the possible emergence paths, some of which allow for GRUE's emergence (see Kay & Maffi, 1999; Kay et al., 1997).

3. Including subsets of everyday colors that are skewed, as seen in regions of desert savanna, rainforest, or snow-bound environs.

4. Figure 5 presents an example of a constant hue page from one such color order system; such pages will be used later to illustrate interpoint-distance model (IDM) analyses.

5. Here *brightness* and *lightness* are synonymous. In addition to these familiar dimensions, other important dimensions can play a role, as shown later. Interestingly, the modeling of many robust dimensional attributes of color appearance space has been largely ignored by both color-naming theorists and critics (see Jameson, 1997, for a discussion).

6. The degree to which they are similar depends on both perceptual and cognitive processing similarities, as well as sociocultural and technological similarities, shared by compared groups. And both dependencies can vary widely (see Jameson, in press).

7. Hardin (1988) also tentatively advances "polarity" as a significant subjective criterion in color processing, but his formulation differs from that proposed in the IDM, primarily due to Hardin's implied linkage between subjective opponency and visual-processing opponency.

8. An asymmetrically distributed partitioning could occur if, in a given Stage II language, a salient sociocultural demand suddenly defined a need to name lightness and saturation differences among the range of colors from a deep red to a purple-red. But for such a case, one should also find evidence for the sociocultural demand and thus identify the effect of this demand given the IDM allowances for cultural dimensions.

9. See Jameson (in press) for a discussion of this latter point as well as discussion of (a) cultures universally reaching a common solution of how to partition and label culturally relevant color appearances and (b) the role-shared cultural agreement in defining normative color category lexicons.

10. Information on Arabic livestock color lexicons was generously provided by Bill Young, Center for the Advanced Study of Language, College Park, Maryland. See also Ingham (1997, pp. 175-176).

11. Examples that can arise from culturally specific demographics also create culturally relative dimensional emphases. One such example is the Caroline Islands achromotope population described by Sacks (1997). As a society, the population has a highly specific manner of describing color and visual appearances due to a wide spread visual impairment of total color blindness and hypersensitivity to light. Their color discourse clearly reflects the different salient dimensions underlying their color-naming system and related cultural practices.

12. Hindsight bias generally encourages a view that seems more predictable than it really is. It may be that Kay and colleagues have revised their formal definition of composite categories to update this aspect of the theory, although recent reports relevant to composites and the World Color Survey (WCS) do not delve into such a redefinition.

13. As well as the intervening stages posited by Kay et al. (1997).

14. Indeed, using a more detailed IDM analysis, a warm/cool partition is a natural consequence of a single partition arising from the dual application of the lightness and saturation dimensions. By IDM theory, such a partition should only be observed in lexicons of Stage I status—as defined by the Berlin, Kay, and Maffi theory—prior to polar differentiation of the lightness and saturation dimensions.

15. This Garner-inspired aim to lexically maximize and spatially regularize named regions of the stimulus domain is an equally important emphasis in IDM's explanation of a GRUE category (Garner, 1974).

16. The development of alternative Stage III and IV paths represented in Figure 1 is described in Jameson (in press).

17. Related results were shown by Indow (1988) for the Munsell color space. Kuehni (2001) also reports a similar number of unit hue differences between red and blue compared to between blue and green. However, it should be noted that the Munsell system uses a purple (red-plus-blue) primary in conjunction with the usual Hering opponents red, green, yellow, and blue.

18. Jameson (in press) argues that individual variability does not prevent a culture from developing a robustly shared color-naming system because variability in color naming is aided by *linguistic charity*—a principle that makes interpersonal communication paramount. Individual variability in color perception and color naming does, however, pose significant difficulties in identifying narrowly defined focal regions that serve as category foci for all individuals within a given culture.

19. Use of the "basic" construct here simply intends to link the present *sinij* and *goluboj* analyses to the existing literature and is not intended as validation of the "basic" construct as typically defined by Berlin and Kay (1969) and colleagues.

20. Note that the three separate dimensions of the Munsell system do not use the same perceptual metric. For example, one Munsell value step is roughly perceptually equal to two Munsell chroma steps (Indow, 2003).

21. All necessary color image-rendering controls aside, this approximated location of *goluboj* was informally offered by one nonnaïve, native-language speaker of Russian when viewing the full-color CRT image of Figure 12. Although a full-color image best illustrates subtle features of hue gradient, even Figure 12's grayscale image illustrates the principle of polar opposition in partitioning the stimulus page presented.

22. Indeed, informal approximations of modern-day *sinij* were displaced from our hypothetical location of proto-*sinij* by one nonnaive, native-language speaker of Russian while viewing the full-color CRT image of Figure 12. In the absence of color-rendering controls, these approximated exemplar locations of *goluboj* and *sinij* only provide an impression one observer's comparative best-example placements and give no information regarding foci that might arise from a formal assessment under uniformly controlled viewing circumstances.

23. According to Pastoureau (2001), historically, diffuse descriptors for blue appearances are found in Latin. Most common was *caeruleus,* which denoted shades green, black, and then blue before it was linked more solidly to blue appearances (Pastoureau, 2001, p. 26). The *blue* term gap in Latin was filled by borrowing color terms for blue from

two other languages: Germanic *blavus* and the Arabic *azureus*. Thus, a “dark” or “saturated” category is further lexicalized on the basis of hue.

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