Science ≠ Imperialism: A response to B. A. C. Saunders and J. van Brakel's "Are there non-trivial constraints on colour categorization?"[1]

(for *Brain and Behavioral Sciences*)

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Introduction: Observation and Inference in *Basic Color Terms*

In 1969, we published a short monograph (Berlin and Kay 1969; hereafter BCT) advancing two broad hypotheses: (1) there are semantic constraints on the basic color lexicons of the world's languages and (2) basic color lexicons grow in a constrained fashion. At the time, we guessed that both sets of constraints must have something to do with universals of color vision, independent of language, although we had no idea what these might be. We expressed this view on the penultimate page of that monograph:

> A fundamental problem which remains unsolved is the explanation for the particular ordering found. Given that cultural evolutionary factors may explain the gross numerical growth in the size of basic color vocabulary, why are terms added in a partially fixed order and why in this particular order? Our essentially linguistic investigations have led, seemingly inescapably, to the conclusion that the eleven basic color categories are pan-human perceptual universals. But we can offer no physical or physiological explanation for the apparently greater perceptual salience of these particular eleven color stimuli, nor can we explain in any satisfying way the relative ordering among them (BCT: 109).

Below, we will suggest that since 1969 modest progress has been made in relating cross-language universals of color naming to properties of the visual system. Before undertaking that task, we pause briefly to reject the S&vB claim that our inference actually went in the direction opposite from the one we reported. We wrote that cross-linguistic investigation had revealed universal constraints on the semantics of color, from which we inferred, in concluding, that these constraints might well be grounded in vision. S&vB claim that the cross-linguistic universals presented by B&K as an empirical finding were assumed *a priori* and somehow built into the experimental procedure, so that the results

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[1] We are indebted to Luisa Maffi for much useful advice regarding all aspects of this reply and to C.L. Hardin for comments on an earlier draft.

were artifactually constrained to turn out the way they did. (We have numbered the sentences in the following paragraph for ready reference.)

> (1) Berlin and Kay assumed that the perceptuolinguistic basic colour system is innate, biologically constrained and (semi-)automatic. (2) In the absence of any reason to suspect members of other speech communities having different automatisms, they felt justified in taking the American English colour lexicon as a standard. (3) Experiments were set up in such a way that performance could be transposed into competence through a generating or translation rule. (4) This revealed that at the meta-level, as in American English, there were exactly eleven BCTs. (5) Although it is suggested that BCTs were the result of cross-cultural empirical research, this lexicon was in fact derived from the most popular American-English colour terms in Thorndike's Teacher's Handbook (via Brown and Lenneberg ([1954]) (S&vB, this issue, page 000).

Sentence (1) is false. BCT contained no assumption, explicit or otherwise, regarding an innate "perceptuolinguistic" system. S&vB offer no evidence for this assertion.

Sentence (2) is false. American English color words were not used as a standard. Again no supporting evidence is presented. English color words were used in BCT to *gloss* universal categories. These categories showed up in the close clusterings of the responses of speakers of twenty languages who were asked to name in their own languages color stimuli identified in the Munsell system of color notation. Writing in English, it would have been perverse to gloss such a cross-language response cluster with *rojo* (Spanish), *krasny* (Russian), *nchi* (Western Apache), or *kula* (Tongan), rather than *red* (English), or to render it with a list of Munsell notations opaque to most readers.

Sentence (3) does not readily yield a straightforward interpretation. Presumably, the words "competence" and "performance" refer to the distinction introduced by Chomsky (e.g., 1965: 3ff). Although we are famililar with the competence/performance distinction, the sentence, "Experiments were set up in such a way that performance could be transposed into competence through a generating or translation rule," is opaque to us.[2]

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[2] For Chomsky, linguistic competence is tacit (unconscious) knowledge of language. Linguistic performance consists in the actual, on-line production and interpretation of utterances. Linguistic performance, according to Chomsky, reflects many psychological

Sentence (4) appears to be saying that the (illegitimate) method described in sentence (3) led to the (improper) conclusion that there exist eleven universal basic color categories. If this is indeed the intended assertion of sentence (4) it is unsupported, although often repeated, by S&vB.

Sentence (5) is false. There is no reference in BCT to "Thorndike's Teacher's Handbook" and there is no reference in BCT to Brown and Lenneberg (1954, hereafter BL).[3] As best we can recall, neither of us has ever mentioned "Thorndike's Teacher's Handbook" in print or in person to anyone, including each other, in this or any connection.[4]

The only evidence S&vB present for the claim that B&K *assumed* a universal language/vision correlation and coerced the cross-language data to support it is the following: "We find we can only understand this work [i.e., BCT] on the assumption that Berlin and Kay had a strong a priori belief that just as 'biological foundations of ...language... must exist for syntax and phonology' so 'basic color lexicons suggest such connections are also...found...in the realm of semantics' (Berlin and Kay 1969, p. 109f)" (S&vB, this issue, p. 000). The passage quoted by S&vB is drawn from the last two sentences of BCT. B&K present this parallel as a tentative conclusion, not as an assumption. That S&vB could understand the text of BCT only by assuming that its authors lied about their assumptions is not a compelling argument that the authors of BCT lied about their assumptions. Others have understood that text without making this assumption.

abilities and disabilities apart from linguistic competence, such as limitations of memory, allocation of attention, perceptual and motor constraints, distractions, and so on. The relevance of this distinction to the empirical method of BCT is obscure. Also obscure are the intended meanings of the expressions "transposed" and "a generating or translation rule" in sentence (3). Readers of this journal who are not linguists should not suppose that sentence (3) uses linguistic terminology in a standard way.

[3] A reference to BL appears in the supplementary Bibliography, prepared by Luisa Maffi (1991), which appears in the paperback reprinting of BCT.

[4] Nor, for that matter, has either of us mentioned Thorndike, E.L., and I. Lorge, *The Teacher's Word Book of 30,000 Words*, New York: Teacher's College, Columbia University, 1944, the only work authored by Thorndike to which Brown and Lenneberg refer (1954: 457).

Empirical Procedures

On our way to suggesting some tentative recent advances in correlating universals of color semantics with properties of the visual system, we will have occasion to review our empirical methods, both in the experiments of the sixties and in more recent investigations. Readers may judge for themselves whether these methods are biased toward finding Western-like semantic structures in non-Western languages. In light of S&vB's claim that Berlin and Kay – and, by implication, others working in the same tradition – have artifactually built a false finding of semantic universals into their method of investigating color naming cross-linguistically, it is worth noticing that both the stimuli and almost all of the procedures used by Berlin and Kay and their associates were taken directly from the classic study of Lenneberg and Roberts (1956, hereafter LR) (see also BL). Both LR and BL were conducted in search of effects confirming the Whorf hypothesis of radical linguistic relativity. Both the LR and BCT, as well as several investigations in this tradition which intervened, have used an array consisting of forty equally spaced Munsell hues at each of eight equally spaced levels of lightness (Munsell "Value") at the maximum saturation (Munsell "Chroma") currently available for each hue/lightness point.[5] In addition, Berlin and Kay and their associates have presented speakers with a series of neutral hues varying in equal steps of lightness. This is not the place to evaluate the psychological validity of the Munsell coordinate system. It suffices here to note that no reason has been proposed by S&vB or anyone else to suppose that choosing this coordinate system for colors, rather than another, tends to impose Western categories on non-Westerners.[6] This same array of color stimuli has been employed repeatedly by

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[5] See, for example Landar, Ervin and Horowitz (1960). BL and Lantz and Stefflre (1964) used slightly smaller sets of Munsell colors, chosen on essentially the same principle: fair sampling of the Munsell space. All of these studies sought to establish relativistic effects in color categorization.

[6] A 'postmodernist' might argue that any coordinate system for color is necessarily Western-biased: since coordinate systems for color are elements of the scientific tradition and the scientific tradition is part of Western culture, no coordinate system for representing the denotata of color words can be legitimately employed in the study of a non-Western language. Acceptance of this view would seem to remove the issue from the scientific arena. We do not know whether or not S&vB currently hold this view. However, in a volume entitled *Post-Modernism and Anthropology* (Geuijen, Raven and de Wolf 1995), Saunders and Van Brakel argue that Kay and McDaniel's (1978) "reductionist argument ... of six basic or atomic colour categories ... to Fundamental Neural Response categories," is invalidated by the prior epistemological principle that "there is no privileged discourse in which what is true is independent of our choices, hopes and fears" (S&vB 1995: 170). The fact that this argument does not appear in their current paper may or may not indicate a moderation of S&vB's position toward one compatible with scientific discourse. It remains unclear whether or not S&vB currently hold that any uniform coordinate system used in color naming research necessarily imposes Western categories on non-Western languages.

researchers looking for relativistic effects. Just as the stimuli used in BCT were the same as those used in the original cross-language study of Lenneberg and Roberts, so were the experimental procedures: color names were first obtained without the stimulus array and then each speaker was asked, for each color term investigated, to indicate (a) all the colors denoted by the term and (b) the color(s) most aptly denoted by the term.

If these were the procedures used in LR, what were the results?

> A comparison of the responses of monolingual Zunis with the responses of English speakers reveals that with only one striking exception most of the color-categories of one language have an equivalent category in the other. The exception, however, is interesting. In English yellow and orange are very sharply defined, separate categories whereas in Zuni (as spoken by monolinguals) there is only one category encompassing both orange and yellow. Even more interesting is the following comparison of the over-all structure of the entire color space in the two languages... (LR: 30)

In their search for relativistic effects, Lenneberg and Roberts go on to characterize some rather subtle statistical differences in their aggregate pictures for their English, Zuni monolingual and Zuni bilingual groups, indicating three respects in which the bilingual group might be considered transitional between the two monolingual groups. They concentrate on the differences, having acknowledged their primary finding to be that the English and Zuni color term systems are on the whole very similar, Zuni simply lacking a separate term for orange and including orange and yellow colors under a single term. We rehearse this ancient history only to make the point that Lenneberg and Roberts were looking for Whorfian effects in their Zuni-English comparison (as were Brown and Lenneberg in their English-internal study). Berlin and Kay borrowed both the stimuli and the elicitation procedures from investigators who were looking for relativistic effects.[7] The fact that the BCT method was closely modeled on that of LR was reported in several places in BCT (p. 3., pp. 103-104, note 3) and so was known to S&vB. S&vB's claim that the findings of BCT are an artifact of Western-biased methodology is not only unsupported: given the source of B&K's empirical procedures, it is prima facie implausible.

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[7] But who were nonetheless punctilious in not exaggerating their successes in this endeavor. For a more recent study of Whorfian effects in the color domain, see Kay and Kempton (1984).

The B&K Munsell stimulus array is shown in Figure 1.

```
              1         2         3         4
   0 1234567890123456789012345678901234567890
A  • ••••••••••••••••white•••••••••••••••••••
B  • ••••••••••••••••••••••••••••••••••••••••
C  • •••••yellow•••••••••••••••••••••••••••••
D  • ••••••••••••••••••••••••••••••••••••••••
E  • ••••••••••••••••••••••••••••••••••••••••
F  • ••••••••••••••green••••••blue•••••••••••
G  • red••••••••••••••••••••••••••••••••••red
H  • ••••••••••••••••••••••••••••••••••••••••
I  • ••••••••••••••••••••••••••••••••••••••••
J  • ••••••••••••••••••black•••••••••••••••••
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Figure 1. Diagrammatic representation of the B&K Munsell color array with English words loosely suggesting the location of the Hering primaries

In Figure 1, Row A comprises 41 pure white chips (Munsell neutral Hue, Value 10). Row J comprises 41 pure black chips (Munsell neutral Hue, Value 1). Column 0 contains ten neutral colors ranging from pure white (A0), through mid-brightness gray (E0, F0), to pure black (J0). Columns 1 through 40 represent equally spaced Munsell Hues, from Munsell Red 2.5 in column 1 to Munsell Red-Purple 10 in column 40. Rows A through J represent equal, descending steps of Munsell Value (lightness) from 10 through 1. Each of the 320 non-neutral chips (that is, those in rows B-I and columns 1-40) is at the maximum saturation available for that Hue/Value combination. The Hues range from yellow-reds (starting in column 1), through yellows, greens, blues, purples to purple-reds (column 40). A color print approximating the original array may be found in the 1991 paperback reprinting of BCT and in Kay, Berlin, and Merrifield (1991).

The World Color Survey

Since BCT appeared in 1969 further work on cross-language color naming has been conducted by numerous researchers in many different languages (see Maffi 1991 and additional items cited in the paper by S&vB under discussion here). Perhaps the most wide-ranging new research carried out since 1969 is that of the World Color Survey (WCS)[8], a large-scale comparative color naming project whose initial data acquisition stage

[8] Robert E. MacLaury's Middle-American Color Survey has also provided extensive new data. See MacLaury (1986, in press a, and references cited in the latter).

was completed in the early 1980s (see Berlin, Kay and Merrifield 1985, Kay, Berlin and Merrifield 1991, Maffi 1991, Kay, Berlin, Maffi and Merrifield in press, Hardin and Maffi in press, Kay, Berlin, Maffi and Merrifield in preparation, MacLaury 1992, MacLaury in press b)[9]. We provide a brief description of the WCS project, its methods, and some of its basic findings, in order to make two points: (1) the methodology is not biased toward imposing Western color categories on non-Western languages and (2) linguistic data do reveal (a) universal constraints on color naming and (b) associations between constraints on color naming and apparent properties of color vision.

The field research for the WCS was conducted by trained field linguists of the Summer Institute of Linguistics (SIL), who collected color naming data using a stimulus array substantially the same as that of B&K. Comparable data on naming ranges and focal choices for basic color terms were collected *in situ* on 110 languages representing a wide range of language families. In most cases twenty-five speakers were interviewed per language. Monolingual speakers were sought insofar as possible. A methodological departure of the WCS from the method used in BCT was that chip-naming judgments were obtained on 330 individual chip presentations rather than on the fixed array of 330 color chips. (Kuschel and Monberg 1974 employed a similar procedure). The individual chips were encased in 35mm photographic slide covers, arranged in a standardized random order, placed in metal slide boxes and sent to SIL field investigators. An identifying numeral (1-330) was printed on the back of each slide for ease in recording. In the naming task, each speaker was shown the chips one by one and asked to name the color. The responses were written in coding booklets that were eventually computerized for analysis.

The coded data of the WCS are represented in several different types of display over the grid of 410 Munsell chips shown in Figure 1.[10] An *individual naming array* shows for a single speaker the naming response given to each of the 330 stimuli in the form of a symbol which is keyed to the native language term by which that chip was named. An *aggregate naming array* shows for a given language the response most often given for each chip, provided that the response reaches a specified frequency, called the *level of agreement.* Thus, each aggregate naming array has a specific level of agreement attached:

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9 Saunders and Van Brakel (1995) review the preliminary analyses of the WCS data made available in microfiche form as Berlin, Kay and Merrifield (1991), making many of the same claims regarding color naming as in the paper under discussion.

10 The displays modeled on Figure 1 depict 410 chips, despite there being only 330 distinct stimuli, because the top and bottom rows of the display (rows A and I) each consist of 41 tokens of a single chip type. That is, row A contains 41 identical white chips and row I contains 41 identical black chips. The effect is something like a Mercator projection of the skin of the color solid, with extreme stretching at the poles.

the x% level of agreement shows the responses for all and only those chips whose most popular response was given by at least x% of the responding speakers. A *term map* presents for a given term a summary of its denotation. Term maps are revealing of the internal structure of (gradient) color categories; the method of their construction is described below. Examples of each of these types of arrays can be seen in Figures 2-4.

Figure 2 presents two aggregate naming arrays for Sirionó, a Tupian language spoken by approximately 500 people in the lowlands of Bolivia.

```
     28% Agreement Level, 7 of 25 speakers
            1         2         3         4
  01234567890123456789012345678901234567890
A ooooooooooooooooooooooooooooooooooooooooo A
B oooooooooo|||||oooooooooooooooooooooooooo B
C o|&&&&||||||||||||*o**o*o*oo*oooooo|&&&|& C
D o&&&&||||||||||||***************o*o&&&&&& D
E •&&&&&|||||||||*******************&&&&&&& E
F •&&&&&&|||||||||*******************&&&&&& F
G •&&&&&•••••••||********************&&&&&& G
H •&&&&&••••••••••******************&&&&&&& H
I •&&&••••••••••••••*•••••••••••**•&•••&&&& I
J ••••••••••••••••••••••••••••••••••••••••• J
         Coverage is 100% (330 of 330)
```

```
     92% Agreement Level, 23 of 25 speakers
            1         2         3         4
  01234567890123456789012345678901234567890
A ooooooooooooooooooooooooooooooooooooooooo A
B  o     o                     ooo  oooo  o B
C o          |                     o        C
D                                           D
E   &&                         *        &&& E
F   & &                                  && F
G •&&&                                   && G
H  &&&                                  &&& H
I                                           I
J ••••••••••••••••••••••••••••••••••••••••• J
         Coverage is 12% (37 of 330)
```

Symbol	Term	Gloss
•	*erondeì*	black
o	*eshĩ*	white
&	*eìrẽĩ*	red
|	*echo*	yellow
*	*erubi*	grue[11]

Figure 2. Two Sirionó Aggregate Naming Arrays (25 speakers, 12 F, 13 M)

Figure 2, with the accompanying key, shows that Sirionó has five basic color terms that can be glossed as black (including brown) *erondeì,* white *eshĩ*, red *eìrẽĩ*, yellow (including orange)*echo,* and grue[11] *erubi.* Each of these five terms is represented in the aggregate naming array corresponding to the 92% level of agreement, and at the 28% level of agreement, the complete stimulus array is covered by these and only these terms.

Sirionó term maps for these five basic color terms are presented in Figure 3. There is a separate map for each term. In the term map for a given term t, each chip c receives a typographical symbol (including blank) of visual 'density' intuitively commensurate with the degree of consensus among speakers regarding the use of t to name c, specifically, commensurate with the proportion of the speakers naming any chip with t who name c with t.[12]

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[11] 'Grue' denotes a category encompassing all of green and all of blue. Sometimes we write equivalently 'green-or-blue'.

[12] If at least 81% of the speakers who name any chip with t name chip c with t, then c receives '#'. If 61-80% of the speakers who name any chip with t name c with t, then c receives '+'. If 41-60% of the speakers who name any chip with t name chip c with t, then

```
.: erondeɨ 'black'

            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B                                           B
C                                           C
D                                           D
E -           .                     .       E
F +       .. ...                            F
G @     .++----.           . .     .        G
H #    .++-#####+-.     .... .. .           H
I # ..-+###+######+-- -.+-++--+-- .. ...  . I
J @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ J

  25 of 25 speakers searched; 24 used term:
1..16,18..25
 Consensus level is 96% (23 of 24 speakers)
```

```
o: eshĩ 'white'

            1         2         3         4
  01234567890123456789012345678901234567890
A @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ A
B #@+#+++##+... .++++-+-++##+###@########## B
C #                . . .- -.-+.+-###+ .     C
D +                              ....       D
E                                           E
F                                           F
G                                           G
H                                           H
I                                           I
J                                           J

  25 of 25 speakers searched; 25 used term
 Consensus level is 100% (25 of 25 speakers)
```

```
&: eɨreɨ̃ 'red'

            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B                                           B
C  .--..                             ...-.- C
D  +++-..                            .-+++- D
E  +####.                           .-+#### E
F  ###@+-                            --##@@ F
G  @@##-                             +++#@@ G
H  ##@#.                            ---###@ H
I  +.-.                            .    -.+. I
J                                           J

  25 of 25 speakers searched; 25 used term
 Consensus level is 100% (25 of 25 speakers)
```

```
|: echo 'yellow'

            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B          .+--+-                           B
C  .  . -+###@###+-.. .  .           . . .  C
D     .-++#+##+++--..                       D
E       .+++#-.++ .                         E
F        .-.-.....                          F
G       .      ..                           G
H                                           H
I                                           I
J                                           J

  25 of 25 speakers searched; 25 used term
 Consensus level is 96% (24 of 25 speakers)
```

```
*: erubi '(blue-focused) grue'

            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B                      .                    B
C                 ..-.......... .           C
D                . ..+-++--+-+++-....       D
E             .  -.-.--++++-++#@+--.        E
F            . ....------+#+-++++--..       F
G                .----+---+-+++#++++..      G
H                ...-----.-----+-+---  .    H
I                  ......   .....+- ..    . I
J                                           J

  25 of 25 speakers searched; 25 used term
 Consensus level is 92% (23 of 25 speakers)
```

Figure 3. Sirionó Term Maps
(# = 81-100% , + = 61-80 % , - = 41-60% , . = 21-40%)

A term map depicts the internal structure of the category denoted by a single color term. Since a term map is based on the naming responses of all cooperating speakers who use the term, it maps the corresponding category at the inter-personal level. High-agreement symbols tend to occur in the interior of categories and lower agreement symbols at the edges. Term maps also give an accurate summary of the degree of consensus among speakers regarding the denotation of a term.

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c receives '–'. And so on, as indicated in the legend above the term maps. The chip(s) with the highest absolute level of consensus (independent of the group they fall in) are taken to represent the focus of t, and are marked by @. At the bottom of each term map is a sentence of the form, "Consensus level is X%, Y of Z speakers." Here, X is the proportion indicated on the map by @; Y is, thus, the number of speaker who name with t the chip(s) which are most often named with t, and Z is the number of speakers who name any chip with t.

Finally, individual naming arrays for two Sirionó speakers are given in Figure 4. Generally speaking, individual arrays illustrate significant individual variation, the two shown in Figure 4 being unusually similar, although this variation does not obscure the patterns that emerge from the aggregate naming arrays and the term maps.

```
            ***  Speaker   8    ***
                     1         2         3         4
   01234567890123456789012345678901234567890
 A ooooooooooooooooooooooooooooooooooooooooo A
 B oooooooooo|||||oooooooooooooooooooooooooo B
 C o&&&|&&|||||||||||**o*oooooo*o*oooo||||&| C
 D o&&&||&&|||||||*|*|***o*****o***oo**&&&&& D
 E .&&&&&&||||||||*|*****************.|&&&&& E
 F o&&&&&&&.||*||*|-******************&&&&&& F
 G .&&&&&|....|.||*************-****-*&&&&&& G
 H .&&&&.....-....*|*****************&&&&&&& H
 I .&..........*..*|*..**......****-&&-&&*&* I
 J ......................................... J
```

```
           ***  Speaker  14    ***
                     1         2         3         4
   01234567890123456789012345678901234567890
 A ooooooooooooooooooooooooooooooooooooooooo A
 B oo||oo|oo||||||oooooooooooooooooooooooooo B
 C o|&&|&||||||||||||*o|oo|oo*o*|.ooo*&&&&&& C
 D .&&&&|&|||||o|||||***********||o*o*&&&&&& D
 E .&&&&&&||||..||*|**************.*.&&&&&&& E
 F .&&&&&|&|.*...*****************..*&.&&&&& F
 G .&&&&&&..*...|||*****************.&&&&&&& G
 H .&&&&&.*-.......***..*.****.****..&&&&&&& H
 I .&|&*............*......*....***...-&&..* I
 J ......................................... J
```

Symbol	Term	Gloss
•	*erondeì*	black
○	*eshĩ̃*	white
&	*eìrẽĩ*	red
|	*echo*	yellow
*	*erubi*	grue

Figure 4. Individual Naming Arrays for Two Sirionó Speakers

Cross-Language Constraints on Color Naming

The WCS data allow us to observe several cross-language generalizations in the color naming behavior of speakers from the 110 languages in our sample. While a full exposition of these interlanguage generalizations awaits a monographic treatment (see Kay, Berlin, Maffi and Merrifield in preparation), preliminary analysis of the WCS data controverts the two substantive points regarding color naming that are advanced by S&vB.

Methodological considerations aside, S&vB make one substantive claim and one empirically investigable theoretical suggestion in the domain of color naming. The substantive claim is that "Linguistic evidence provides no grounds for the universality of basic colour categories" (S&vB, this issue, p. 000). S&vB's theoretical suggestion presupposes the falsity of this claim. S&vB cite approvingly Tornay's suggestion that it is

Western colonialism, rather than the biology of color vision, which accounts for the universals proposed by B&K in the semantics of color terms: "Alternative explanations of tendencies to basic colour categories across languages were not considered [in BCT]. For example, Tornay (1978: xxxi) proposed the history of the progressive domination of the West and its values accounts for apparent universality. This seems a plausible suggestion with respect to what is often quoted as Berlin and Kay's most solid result ... " (S&vB, this issue, p. 000). According to S&vB, there are no cross-linguistic constraints in the semantics of color and it is "the progressive domination of the West and its values" which accounts for them!

The WCS data refute each of these claims.[13] Specifically, the data reported below support the hypotheses that (1) there are universal semantic constraints in color naming and (2) cross-language similarities can't *all* be explained by processes of diffusion from one language (e.g. a colonial language) to another (e.g., a local language).[14] Specifically, while all the politically dominant European and Asian languages have basic terms distinguishing red from yellow and basic terms distinguishing green from blue, many unwritten languages (as well as documented earlier stages of the major written European and Asian languages) reveal the presence of the underlying universality of the red, yellow, green and blue percepts by encoding in one basic term either a category that covers just what is covered by *red* and *yellow* in English (equivalently, by *mérah* and *kuning* in Bahasa Indonesia), or a category that covers just what is covered by *green* and *blue* in English (equivalently by *yaroq* and *kahol* in Hebrew), or both. There are also rare cases of yellow-or-green categories, but no cases of categories denoting just red-or-green or just yellow-or-blue, a result consonant with opponent theory.

The fact that languages which don't have separate basic terms for each of the six Hering primaries tend strongly to contain terms whose denotations cover sets of two or three perceptually adjacent Hering primaries supports the universal finding that basic color systems are based, with rare and partial exceptions, on the Hering primaries red, yellow, green, blue, black, white.[15] The existence of such composite categories, as they were

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[13] Since the first claim is false and the second claim presupposes the first to be false, the second claim is coherent, but it is nonetheless false.
[14] There is of course no question that interlanguage influence is a major factor in color term evolution. See, for example, the discussions in BCT on Javanese (pp. 87f), Siwi (pp. 89f), Lebanese Arabic (p. 91), Bahasa Indonesia (p. 91), Bulgarian (pp. 41, 92), Swahili (p. 40), Korean (p. 40) Malay (p. 97) and Tagalog (p. 100).
[15] See Kay and McDaniel (1978), among others, as listed in Kay and McDaniel (1978: 620, note 5).

termed by Kay and McDaniel, shows that the constraints on color naming shared by colonial and local languages can not all be due to dissemination from the former to the latter because there is nothing in English, French, Spanish, German or Dutch (the major languages of Western colonialism) that could induce blue-or-green or red-or-yellow categories, for example, in the languages of the colonized peoples. (Not to mention that (1) many local languages were reported to have composite categories at the time of contact with the West and (2) earlier stages of the now dominant European and Asian languages (e.g., Latin, Japanese) contained composite categories (e.g. green-or-blue: L. *viridis*, J. *ao*), and lacked terms for some of the Hering primaries (e.g., Latin 'blue', Japanese 'green').[16]

The array of composite categories in the WCS data reported in Kay, Berlin and Merrifield (1991) are all reducible to unions of Hering primaries. Kay and McDaniel (1978) proposed that the categories denoted by the basic color terms of the world's languages are of three types: (1) composites, the unions of two or more Hering primaries, e.,g., red-or-yellow, green-or-blue, (2) Hering primaries, e.g., red, green, and (3) intersections (mixtures) of Hering primaries, e.g., orange [red-and-yellow], purple [red-and-blue]. The WCS data confirm that all categories denoted by basic color terms tend strongly to fall into one of these types.[17] The fact that local languages often contain categories of the composite type, which are absent from the languages of the colonizers, shows that not all cross-language constraints on color naming can be due to contact between colonial and local languages.

At the time of this writing, sixty-three of the 110 languages in the WCS sample have been fully analyzed.[18] Of these forty-six have a basic color term that translates well into English as *red* (or into Western Apache as *nchi* or into Tongan as *kula*, etc.) Forty-one have a separate yellow term (including two slightly unclear cases). Twenty-four have a separate green term. These twenty-four include five cases in which it is somewhat unclear whether the term marks a separate green category or a category focused in green but

---

[16] Kristol (1980) points out that several modern Italic dialects have never developed a basic term for blue, retaining a reflex of *viridis* to cover all of green-or-blue. (He also proposes that *caeruleum* was a basic term in classical Latin for blue, but his arguments for this are not persuasive and the weight of evidence in André's comprehensive (1949) study of Latin color terms suggests that *caeruleum* was never a basic color term.)
[17] There are infrequent exceptions (or possible exceptions). See, for example, the discussion of the peripheral red category in Kay, Berlin, Maffi and Merrifield (in press).
[18] All the papers cited above that reported on the WCS data have been based on preliminary and partial analyses. For example, term maps were not generally available, and the data contained errors, including coding errors, which have now been corrected.

extended throughout grue. Nineteen languages show a separate blue term, including five cases that are possibly blue-focused grue. Additionally two Spanish-influenced languages have adopted the *celeste* 'light blue'/*azul* 'dark blue' distinction into their basic color vocabulary. Native words predominate for all categories, although there are borrowings from both European and non-European languages.

Given previous experimental examinations of cross-language color naming going back as far as LR, this degree of similarity between unwritten languages and familiar European ones is not surprising. More interesting because more exotic are the composite categories observed in this sub-sample of sixty-three unwritten languages.[19] The term maps for the nineteen green-or-blue and the nine red-or-yellow terms found in these sixty-three languages are presented below.

In BCT, only two of the twenty languages in our original sample exhibited grue categories. On the basis of our survey of the literature, we were able to document another seventeen languages whose descriptions suggested to us that they too included a green-or-blue composite color category. The WCS data reveal an additional nineteen experimentally investigated languages which show grue as a well established category. The denotative range of grue in these nineteen languages follows a narrow pattern, as can be seen in Figure 5.

---

[19] The selection of this sub-sample from the full sample of WCS languages is, with haphazard exceptions, alphabetical. The selection of the WCS sample from the full population of the world's unwritten languages was determined primarily by the presence or absence of an SIL missionary linguist in the field area.

Colorado (Ecuador)

losimban

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C               .--++-+---- . .             C
D               .#+##+++--------.           D
E              .-####+@+++---+++.           E
F              .+#########++--+---          F
G            ...-##@@@#@##+-+-++--.         G
H             ..-#########+-------..        H
I                +++#++-++.-..-.-.          I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Bauzi (Indonesia)

gahana

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B              .                            B
C              -.+#+#-#.+..                 C
D             ..+##@@########+-.            D
E            .-.-###@#@##@++@+##-.          E
F          . .--###@#@#@###+#+-++-  .       F
G            .  -###@@####+-++##--- .       G
H                 -++#++#+++-+-++--.        H
I                 ...+-. -- ...- --         I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Berik (Indonesia)

tialaikikini

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C                ----+.--...                C
D               .+++++++-++++-..            D
E               .--++++@-+--+---            E
F            ...----++++++-.-- ..           F
G             ...-++--++-----.. .           G
H                ..------....               H
I                   .   .                   I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 80% (20 of 25 speakers)
```

Bhili [Rajasthani] (India)

nilɔ

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                   . ..                    B
C              ..#+@#####+#+-.-.            C
D             ..+#@@@##@##@###+-.           D
E             --+#@#@@@@#@#######.-         E
F            .-+##@###@@@###@##+++..        F
G            ---+@@@##@@#@######++.-.       G
H              .-##@#@@##@#+#-++#+..        H
I                .+++++.++------+---        I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Cavineña (Bolivia)

sahuada

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                     ..+   ..              B
C              ..##+#+###+#+--+.+           C
D              .+@##@@@######@##+-.---.     D
E            .+-###@##@######@@#++++-+.     E
F            .+++@#@@@@@@@@#@#######++.     F
G            .-.#@@@#@@@@##@##@#@###+--.    G
H             ..-##@#@#@#####+#@#####++     H
I  .             -++#+#+++-+-++-###+#+--+.. I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Cofán (Ecuador)

inzia

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                     . -                   B
C              . +++#++##+--..- .           C
D              .-####@#@###+####-           D
E             - ##@##@##@@##@#@@+..         E
F             -+#@@@@@@@@@@@@##@#-.         F
G            .+-+##@@@@@@#@#@@###+.         G
H               -##@@@@@#########-          H
I                .-+#+--+# ---+.+-          I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Ese-Ejja (Bolivia)

tahua

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                     .                     B
C              ..+++#++---... .             C
D              .-#####+#+++--+.-.           D
E            ...-##@#####++-++#+..          E
F             .-##@#######++#++++- . .      F
G             .--##@#######-++#++#..        G
H             ..-##@#@####+++-+#++.. .      H
I                .--#++-+-.-----#..  .      I
J                                           J

  25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Apinayé (Brazil)

grãgrã '

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B              .       .                    B
C         . ..-+.+#++-++--.-..-             C
D        .  ..--########++++++++-           D
E        .   -+.+####@######+###+--         E
F              .--#######+##++#+##-...      F
G              ..-+-######+#-++###--.- .    G
H                 --###+++#-+--##++.-...    H
I                  ..+-. ..  .-+.--         I
J                                           J

  30 of 30 speakers searched; 30 used term
Consensus level is 100% (30 of 30 speakers)
```

Cayapa (Ecuador)

lush-

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C                -+++--.---   . .        .  C
D               -#####+#+++-++--.    .      D
E             -.-##+####+#+++#+#-... .      E
F             -.-################--...      F
G            .  -#+#####@@#++#####+#..- .   G
H               .-+#####+#+++++###++- .     H
I                ..-#++.-+.-.-+.+-..    .   I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)

Guarijío (Mexico)

siyóname

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                  .-+.+.. . .              B
C                ##########++++--           C
D               -+#@@@@@#@#@@####-. .       D
E             -.+#@@@@+@@@@@@@@@@#++        E
F             .+###@#@@##@@@@@##@#++..      F
G             ..+##@@@@#@@####@###+-.-      G
H               ..+######+#+#+###+++- .     H
I                  .-++-.+-.-.---++.. ..     I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)

Iwam (Papua N. Guinea)

prainan

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                  ..  -.                   B
C              -.+--+-+-.---- -..           C
D              .-+++++-+---+-----           D
E            .-.+@++++++-++.-+++.-.         E
F          . .--+++++++++++-++--+..         F
G              .--+++--+++@+--++-- .        G
H    .           -++++---+-..-----..        H
I     .            .+.. -    ...-           I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 84% (21 of 25 speakers)

Shipibo (Peru)

yancon

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                 .  ..-.                   B
C              ..# +#--#-.--- # ..  . .     C
D               --+#.+###@###++@-#+.  .- .. D
E     .       . -++@+@-@+++++###@+-#        E
F .            ..#-##+##@@##-@++#+ -.       F
G          .  -.-.@#-#-###--@@@@+##         G
H  .          - ..+-#--+-##@-@@#+##...     H
I                 . .# . ---+--#.##. ... .   I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)

Kemtuik (Irian Jaya-Indonesia)

di suaki

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C                  --+--.-...                C
D                -.+++.+-+---..             D
E                --+++@+------..            E
F               .@-++@+@++---....           F
G                @+-+-++@---..-.            G
H               .--+--++-+..-..             H
I                  ..... .. -                I
J                                           J
```

25 of 25 speakers searched; 20 used term:
2..5,7..10,12..18,20..22,24,25
Consensus level is 75% (15 of 20 speakers)

kiki

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C                 ..-..--..                  C
D                ..--.----..  .              D
E                .-@.--...-. ....            E
F               .-.-.---..- ...              F
G               ....---.- .-   .             G
H                 ...-...  .    .            H
I                 .. @.                      I
J                                           J
```

25 of 25 speakers searched; 22 used term:
1..13,15..18,21..25
Consensus level is 60% (13 of 22 speakers)

Sirionó (Bolivia)

erubi

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                       .                    B
C                  ..-.......... .           C
D                 . ..+-++--+-+++-....       D
E              .  -.-.--++++-++#@+--.        E
F             . ....------+#+-++++--..       F
G                .----+---+-+++#+++++..      G
H                ...-----.-----+-+--- .      H
I                  ......   .....+- ..     . I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 92% (23 of 25 speakers)

Yaminahua (Peru)

dada

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                       .                    B
C              . -+-#-#---++..-              C
D               -+-+#+###+++++++#-. .        D
E               .+-+++#+@+######@+--         E
F            .  -+-++###+#+###+++-- .        F
G             . .#+++#+++++++++++-...        G
H                 ..-#----+-------- .        H
I                   ....       . ..          I
J                                           J
```

25 of 25 speakers searched; 25 used term
Consensus level is 96% (24 of 25 speakers)

Jicaque (Honduras)

tsu

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                            A
B                                            B
C              . ++-#-+--.- ..-              C
D               .++#+#+@+#+++++#-.           D
E               .@++@@###@#+@@@@#--          E
F             .+-#+@@@####@##@@@#@-..        F
G           . .--@+@@@##@@+@@#@@@@+-.        G
H             -+-+@@+@@@@#@+##@###-.         H
I               .---+#+++#-+++#+##@          I
J                                            J

   10 of 10 speakers searched; 10 used term
 Consensus level is 100% (10 of 10 speakers)
```

Huasteco (Mexico)

yašniʔ

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                            A
B               ...-++-#.+ ...               B
C              ..@#@@@@#@@+++--+-            C
D              -#@@#@@@##+++------           D
E            ..-@@@@@@#@##+------.           E
F            -+##@@@@@@@@#+------.           F
G             ++#@@#@@@@@@#++-----           G
H             +##@@#@@@@@@##+----.           H
I                 @@#@@@####++----           I
J                                            J

   25 of 25 speakers searched; 25 used term
 Consensus level is 100% (25 of 25 speakers)
```

Didinga (Sudan)

culak

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                            A
B                  + -## .                   B
C              @#-####@@@@##@@#+.        +   C
D              .@#@##@#@##@#@@@#.    +       D
E             ..+@@#@#+##+##@@.@@       .    E
F              ###@#@@@@##@#@@##@            F
G               +@#@#@.##@#.@#@+#            G
H           +     @@@@@##@@ + . .+           H
I                 +   -@                .    I
J                                            J

   25 of 25 speakers searched; 25 used term
 Consensus level is 100% (25 of 25 speakers)
```

Chayahuita (Peru)

canin

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                            A
B                 ..++#####+##+.             B
C                 ###@@@@@##@#@#@#+-.        C
D                .##@@@@@#@@@@@@@@##..       D
E               ..#@@@@@@#@@@@@@@@@#-        E
F              .-+@#@@@@@@@#@@@@@@@@+-       F
G               -+@@@@#@@@@@@#@@##@#+-       G
H               .-@#@@@@@#@#@@@@@#@#+--      H
I                 #+@@@@#####@@@@@@#++--.    I
J                                            J

   25 of 25 speakers searched; 25 used term
 Consensus level is 100% (25 of 25 speakers)
```

Figure 5. Green-or-blue in 19 Languages

It is clear that a term covering just the percepts of green and blue is a popular choice for languages which do not have independent green and blue terms. Sometimes the highest level of consensus is shaded toward green (Colorado, Ese-Eja), sometimes toward blue (Sirionó, Yaminahua). Often it is fairly evenly distributed. There is also some variation regarding the degree to which purple is included in a predominantly green-or-blue term. Compare, for example, Shipibo with Hausteco.

Red-or-yellow terms are less frequent than green-or-blue terms in this sample, as may be predicted from the fact that separate red terms and yellow terms outnumber separate green terms and blue terms. (If a language has distinct basic terms for red and yellow it does not by definition contain a basic term for red-or-yellow. See BCT: 5-6.) The term maps for the red-or-yellow terms in the current sample are shown in Figure 6.

Ejagham (Nigeria, Cameroon)

ébí

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B           .. .                            B
C  +++-+-#####+..                    -.#+## C
D  #@##@@@#+#+-..                  . +#@@## D
E  @@@@@@###.-                     .-++@@@@ E
F  @@@@@##-.                         +#@@@# F
G  @@###.-..                        .+++##@ G
H  @@@@-.                           .-+#### H
I  -++-                                --++ I
J                                           J

 25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Gunu (Cameroon)

goɛla

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B          ...                              B
C  +#+++.-----.                      --#+++ C
D  #+@###+...-                       --#### D
E  @##@##--. .   .                 ..-+#@@# E
F  ####@#-...                       .-+#### F
G  #####--                         . +++### G
H  ####+. .                        ..--#+#@ H
I  ++#.                            .   --++ I
J                                           J

 25 of 25 speakers searched; 21 used term:
       1,3..11,13..15,17,18,20..25
Consensus level is 100% (21 of 21 speakers)
```

Konkomba (Ghana)

maman

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C  -+++--.---  .                     . ---- C
D  #+######+.-.                      +-+#++ D
E  @@@@@#++-.                      ..+##### E
F  @@@@##+-- .                     . +##@@@ F
G  @@###--.                        .-+###@@ G
H  #@@#---.                         +++##@# H
I  +++-..                          ....---- I
J                                           J

 25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Múra-Pirahã (Brazil)

bi^{3}i^{1}sai^3

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B                                           B
C  +#+-. .--+-                       -.#### C
D  @#@##++#.-.                       -+@### D
E  @@@###+-.                       .-##@@@@ E
F  @@###+-                          -#@@@@@ F
G  @@### .                         --###@@@ G
H  #@@@.                           .+##@@@@ H
I  ++-.                            - -.+### I
J                                           J

 25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Bété (Ivory Coast)

zɛli

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B            .                              B
C  +++++.++##...                     . -+++ C
D  #@####@##++-..                    ++###+ D
E  @##@@##+-.                      ..-+#@#@ E
F  @@#@@#-...                        -##@@# F
G  @@###-.                           +++#@@ G
H  @#@#-.                           . .#### H
I  -..                                 ..+. I
J                                           J

 25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Chácobo (Bolivia)

shini

```
             1         2         3         4
   01234567890123456789012345678901234567890
A                                           A
B            .                              B
C  ---.-+-.-..                       ..--+- C
D  +++#-#++...                       .#+++- D
E  #####+-..   .                   ..-+#+## E
F  ###@##+.                        . .+#### F
G  ####+..                         ..+-++## G
H  ###+.                            . -++## H
I  ...                                  --. I
J                                           J

 25 of 25 speakers searched; 25 used term
Consensus level is 100% (25 of 25 speakers)
```

Nafaanra (Ghana)

nyiɛ/nyɛ

```
            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B   -.  .   ---.  .                         B
C  ###+##@@#@##.                     ..+#@# C
D  #@#@#@#@#++-                     .-#@@## D
E  #@####@@+-#.                      #+#+#@ E
F  @++@@#+-+.                        +###@@ F
G  @#@@@-#.            .             ####+# G
H  @@##+- .                          .+@++# H
I  ++++ .                              ++#+ I
J                                           J

  29 of 29 speakers searched; 29 used term
     Consensus level is 100% (29 of 29 speakers)
```

Yacouba (Ivory Coast)

-zaôndheu

```
            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B .             .         . -  -   . .      B
C  ++--..--#.-             -          ..-+- C
D  #+#+##++++-     .               . ++##-# D
E  ++###@-##..          -          .--###@+ E
F  ##+@###--.        .   .         ..--#@## F
G  #@-#+--  -       .              .-###+#@ G
H  ###++                   ..   ...--+++#@ H
I  -++.              -              . .-+.+ I
J                                           J

       27 of 27 speakers searched; 27 used term
```

Wobé (Ivory Coast)

-sain'

```
            1         2         3         4
  01234567890123456789012345678901234567890
A                                           A
B           .-..                            B
C  #@#+###@@@#+#.                    ..###@ C
D  @#@@#@@@@@##+-                    +@@@@@ D
E  @@@@@@@@###++.                  -+#@@@@@ E
F  @@@@@@#@#++++.                  -.@@@@@@ F
G  @@@@@##++-..                    -+@@@@@@ G
H  @@@###+-.                       .-+#@@@@ H
I  ####-.                          .---+### I
J                                           J

  25 of 25 speakers searched; 25 used term
    Consensus level is 100% (25 of 25 speakers)
```

Figure 6. Red-or-Yellow in Nine Languages

The data just reviewed make it clear that, contrary to the claims of S&vB, (1) linguistic evidence provides "grounds for the universality of basic colour categories," and (2) a substantial fraction of this evidence cannot be explained by "the progressive domination of the West and its values."

Color Naming Universals and Color Vision

In this comment we have discussed the red-or-yellow and green-or-blue composites to the exclusion of the other composite categories identified by Kay and McDaniel (1978) and integrated into a developmental model in Kay, Berlin, Maffi and Merrifield (in press). One reason for this is that these two composites, based on cross-language color naming data, correspond precisely to the two channels of hue information at one stage of a recent four-stage model of color perception which is based on a wide range of neurophysiological and psychophysical data (De Valois and De Valois 1993, 1996). Although there is much anatomical and physiological support for the earliest stage of the De Valois' model, expecially involving cone types, frequencies of cone types, linkage of cones to horizontal and/or bipolar cells and behavior of all these types of cells, De Valois and De Valois do *not* claim that the stage referred to here, their stage 3, whose output consists of distinct red-or-yellow and green-or-blue channels, corresponds to a particular anatomical structure. Nevertheless, it is interesting that a multi-stage model of color perception based on neurophysiological data posits a stage with two channels of hue response, red-or-yellow and green-or-blue, while cross-linguistic color naming research independently establishes basic color terms denoting red-or-yellow and green-or-blue categories to be widespread in languages which do not have separate basic color terms for all of the Hering primaries.

In the De Valois model[20], combined spectral and spatial opponency at the level of the midget bipolar cells, created by the complex connections among horizontal cells, individual cones and bipolars, produces six kinds of cells at the second stage of the model: L_o cells respond positively to L cones and negatively to the average of all cones weighted by their relative frequencies, $–L_o$ cells respond negatively to L cones and positively to the same weighted average, M_o cells respond positively to M cones and negatively to the weighted average, $–M_o$ cells respond negatively to M cones and positively to the weighted average, S_o cells respond positively to S cones and negatively to the weighted average, and $–S_o$ cells respond negatively to S cones and positively to the weighted average. At stages 3 and 4, the L_o, $–L_o$, M_o, $–M_o$, S_o, and $–S_o$ signals are combined in two steps, as indicated in Figure 7. (Figure 7 is an abridgment of Figure 6 of De Valois and De Valois 1993, omitting the treatment of luminance information).

Stages 3 and 4 of the Model of De Valois and De Valois (1993, 1996)

L_o + $–M_o$		Stage 3	M_o + $–L_o$	
+ S_o ↓ Red	+ $–S_o$ ↓ Yellow	Stage 4	+ S_o ↓ Green	+ $–S_o$ ↓ Blue

Figure 7

At Stage 3, there are two channels (L_o + $–M_o$) and (M_o + $–L_o$). At the fourth stage (1) the former is divided into red and yellow by the addition of S_o and $–S_o$, respectively and (2) the latter is similarly divided into green and blue by the addition S_o and $–S_o$, respectively. The two outputs of hypothetical stage 3, *if some neurological structure should correspond to this stage,* would give us a neurological basis for the red-or-yellow and green-or-blue categories so often observed in the color vocabularies of local languages. We repeat that De Valois and De Valois make no claim for the italicized hypothesis. Still this suggestive correspondence between, on the one hand, higher-level outputs in a model based on statistical analysis of individual cell behavior and, on the other, findings in cross-language color naming appears worthy of further investigation.

[20] Actually, in one of two versions of the model. The difference between the two versions is irrelevant here.

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