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Color naming and the shape of color space

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Abstract

Color naming in the world's languages has traditionally been viewed as reflecting either a universal set of focal colors, or linguistic relativity. Recently, a different view has gained support: color naming may be accounted for in terms of the overall shape of perceptual color space. Here, we show that the new shape-based perspective can clarify which languages have color-naming systems that deviate from what universal forces would predict. Specifically, we find that the color-naming systems of two languages that have been held to counterexemplify universals of color naming—Pirahã and Warlpiri—are in fact consistent with the structure of color space. In contrast, two other languages that have not yet been the focus of much attention—Karajá and Waorani—are apparently inconsistent with that structure in a substantial way. We propose that the notion of 'fit to the shape of color space' provides a useful and objective means of determining which languages have genuinely unusual color-naming systems.

Keywords
color terms, color categories, semantic universals, linguistic relativity, cognitive modeling

1. Introduction

An influential view of color naming hold s that across languages color categories are projected from a limited set of universal focal colors (**Berlin & Kay 1969**). A contrasting relativist view holds instead that color categories are defined at their boundaries by linguistic convention, which varies across cultures (**Roberson et al. 2000**). Each of these views is partially supported by, and partially challenged by, existing empirical data. There are universal tendencies in color naming (**Kay & Regier 2003**, **Lindsey & Brown 2006**), and the best examples of color categories across languages tend to fall near the proposed focal colors (**Regier et al. 2005**); these findings support the universal-foci view and undercut the linguistic-convention view. However, other findings point the opposite way. The best examples of some color categories fall far from the proposed foci. And sometimes languages with similar color-naming systems, with categories that appear to be organized around the same set of foci, differ in their placement of category boundaries (**Roberson et al. 2005**)—

suggesting that category extension is not determined exclusively by the foci, and may be determined to some degree by linguistic convention or other nonuniversal forces.

Jameson and D'Andrade (1997) proposed an account of color naming that has the potential to resolve this tension. They pointed out that the shape of perceptual color space is roughly that of an irregular globe, with large protrusions and indentations across its surface. The degree of protrusion of any particular hue/lightness combination represents how saturated that hue/lightness combination can become. For instance, focal yellow can be highly saturated, as can focal red, so there are 'bumps' at these positions on the globe, among others. In contrast, the blue-green area cannot be highly saturated, so this area of the globe is less elevated. Jameson and D'Andrade suggested that general principles of categorization, operating over this irregular surface, might account for universal tendencies in color naming. **Regier and colleagues (2007)** formalized this suggestion, tested it against empirical data from a wide range of languages, and found **[End Page 884]** support for it. They first defined the WELL-FORMEDNESS of a color-naming system as the extent to which that system maximizes perceptual similarity of colors within a category and minimizes it across categories (**Garner 1974**), with similarity determined in the CIELAB color space, which can represent surface irregularities like those described above. They then found that: (i) theoretical color-naming systems that globally maximize well-formedness are qualitatively similar to color-naming systems found in some languages; (ii) across languages, attested color-naming systems tend to have higher well-formedness than do unattested systems of comparable complexity; and (iii) small differences in the placement of category boundaries sometimes correspond to only slight differences in well-formedness—which may explain why some deviation from universal tendencies is observed empirically. Overall, they concluded that color-naming systems in the world's languages reflect near-optimal partitions of perceptual color space—a proposal that explains universal tendencies while also allowing linguistic convention some role in adjusting those tendencies.

This newly supported 'shape-based' account of color naming shares features with both the universal-foci account and the linguistic-convention account with which it is traditionally contrasted. Like the universal-foci account, the shape-based account holds that there are universal perceptual constraints on the position and shape of color categories. These are soft constraints, however; they do not flow from a limited set of privileged focal colors. Instead, in a natural generalization of the universal-foci account, all colors are focal (perceptually salient) to some degree—namely the degree to which that hue/ lightness combination protrudes from the surface of the bumpy sphere—and universal tendencies stem from simple clustering principles operating over the resulting landscape. Linguistic convention may then play some role in determining just which near-optimal configuration a particular language adopts.

Several languages have been proposed to lack color-naming systems altogether, or to have color-naming systems that are unusual or exceptional. In this short report, we argue that the shape-based perspective can illuminate these issues. We consider two languages, Pirahã and Warlpiri, for which it has been claimed that what appear to be color terms are in fact not that. We analyze these two disputed systems and find that they reflect the universal structure of perceptual color space as do color-naming systems from many other languages—suggesting that these disputed systems are color-naming systems after all. In contrast, we show that two other languages that have not yet received much attention, Karajá and Waorani, have color-naming systems that deviate considerably from what the structure of color space would predict. We conclude that while some languages do have genuinely exceptional color-naming systems, they are not the languages that have been held up as such in the literature.

2. Pirahã

Everett (2005:627–28, 642) has claimed that the Pirahã language lacks color terms. In support of this claim, he points out that color names in Pirahã are morphologically complex, rather than monomorphemic. For instance, the expression for the Pirahã color category that includes black is glossed by Everett as 'blood is dirty' (p. 627). Moreover, Everett claims that there is substantial variation across speakers in how colors are named. These two observations taken together suggest a view of Pirahã color names as idiosyncratic coinages, composed on the fly by particular speakers to express particular colors—rather than a stable and widely shared set of standard color names. More broadly, Everett argues that the Pirahã have a general cultural preference favoring immediate experience and disfavoring abstraction, and that the proposed absence of abstract named color categories in the language is consistent with this cultural preference (p. 642). **[End Page 885]**

Color-naming data from Pirahã were systematically collected by Stephen Sheldon in 1977 as a part of the World Color Survey (**Kay et al. 1997**). These data show substantial agreement across Pirahã informants both on the list of multimorphemic expressions that they supply as color names, and on the denotation of those names—that is, the set of colors picked out by the names. This suggests, in contrast, that color expressions in Pirahã are not highly variable, but are instead widely shared within the society and reasonably stable in reference. Still, this consensus may be misleading. As both **Everett (2005)** and **Kay (2005)** report, Sheldon found that the Pirahã informants consulted among each other during the color-naming task, and so were not interviewed individually; hence, any consensus may reflect their interactions at test rather than a more stable linguistic reality. The only way to settle this question of stability is to again collect data among the Pirahã without allowing interinformant consultation at test. Everett plans to do this (p.c.).

But there is another means of addressing the broader issue—whether Pirahã has color terms like those of other languages—which can be pursued using available data. Everett has claimed both (i) that Pirahã color naming is not widely shared or stable in the population, and (ii) that the Pirahã language avoids abstract color categories like those of other languages, in line with the proposed Pirahã emphasis on immediate experience. We cannot test the first claim given the possibly contaminated Sheldon data, but we can provisionally test the second. If it were to be established that the Sheldon data reflect the universal structure of perceptual color space in a manner comparable to the systems of other languages, that would suggest that speakers of Pirahã, in at least some circumstances, behave as if they have abstract color categories like those of other languages. We tested this question using an analysis method derived from the shape-based perspective described above—a method that has already been applied to many other languages (**Regier et al. 2007**), enabling comparison.

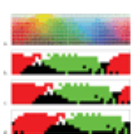

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Figure 1.
(a) Standardized color grid, and Pirahã color categories relative to that grid, shown (b) unrotated, and rotated (c) 4 and (d) 8 hue columns. Each colored region corresponds to a named color category in Pirahã.

Figure 1a shows a standardized color grid based on the Munsell color order system and often used in color-naming research.[1] **Figure 1b** shows the color-naming system **[End Page 886]** of Pirahã, according to the disputed Sheldon data, mapped against this grid. Each colored region corresponds to a named color category in Pirahã. The map was obtained by recording, for each color in the grid, the color expression most commonly used to name it in Pirahã. There are four categories in all, corresponding loosely to white, black, red/yellow, and blue/green.

To test whether this system reflects the structure of perceptual color space, we compared it to a set of comparable systems derived from it by rotation in the hue dimension, as illustrated in **Fig. 1c,d**. Specifically, we rotated the Pirahã system by two, four, six, and so on hue columns, producing a set of nineteen hypothetical variants of Pirahã centered at points evenly spaced around the entire hue circle. We reasoned that if color categories in Pirahã reflect the structure of perceptual color space, then the attested (unrotated) Pirahã system should have higher well-formedness than any of the rotated variants. This prediction follows from the hypothesis that the natural boundaries delineate near-optimal partitions of color space, whereas boundaries in the rotated variants have been deliberately shifted away from their hypothetically optimal positions. This prediction was confirmed. **Figure 2** shows the well-formedness of the actual Pirahã system compared to each of the rotated variants. The actual Pirahã system has greater well-formedness than any of the rotated variants. In this sense, the Pirahã color-naming system, at least according to the disputed Sheldon data, 'fits' the structure of perceptual color space.

Click for larger view

Figure 2.
Well-formedness for Pirahã when rotated 0, 2, 4, 6, etc. hue columns. The configuration that yields greatest well-formedness is the unrotated (attested) version.

Regier and colleagues (2007) performed a rotation analysis of this sort for each of the 110 languages in the World Color Survey (WCS). The results are shown in **Figure 3**, averaged over all WCS languages. This aggregate analysis included the four languages we report on here; the results for individual languages have not been reported previously. The qualitative pattern obtained for Pirahã tends to hold across languages: as a general rule, the color-naming systems of the world's languages fit the structure of perceptual color space better than do rotated variants centered elsewhere along the hue dimension. This pattern held for most (eighty-two of 110) of the languages surveyed. Interestingly, this pattern also held for Berinmo, another language that has been claimed to counterexemplify universals of color naming (**Roberson et al. 2000**). **[End Page 887]**

Click for larger view

Figure 3.
Average well-formedness for 110 WCS languages when rotated 0, 2, 4, 6, etc. hue columns.Across languages the unrotated natural system tends to have highest well-formedness, as in the Sheldon Pirahã data. (Adapted from **Regier et al. 2007**.)

Why use rotation to test fit to the shape of color space, and why rotation in hue in particular? Rotation allows one to compare an actual color-naming system to variants of that system that differ only in their positioning in color space, such that any differences in well-formedness are attributable solely to that positioning of the categories relative to the shape of the space, rather than to differences in complexity, noisiness of the data, and so forth. Rotation in hue, rather than lightness, is a particularly appropriate means of testing fit to the shape of color space, because hue is a privileged dimension of color, as reflected in its prominence in the color-naming literature (see n. 1 of **Berlin & Kay 1969**, which lists several examples). Finally, since many other languages have already been shown to be near-optimal as assessed by this method, it is natural to analyze contested systems using the same method, to gauge their comparability to these other systems.

We conclude that color naming in Pirahã, according to the data collected by Sheldon, fits the structure of perceptual color space in a manner comparable to color naming in most other languages. Even if the Sheldon data turn out to have been corrupted by nonindependence of individual speaker tests, it appears that Pirahã speakers, in at least some circumstances, behave as if they have abstract color categories like those of other languages.

3. Warlpiri

Wierzbicka (2008) argues that the Warlpiri language lacks color terms. Specifically, she argues that what have been taken to be color terms in Warlpiri are in fact not that. At the core of her argument is the fact that Warlpiri lacks a word for 'color'. Given this absence, Wierzbicka argues, it would be an unjustified cultural imposition to assume that Warlpiri speakers have a CONCEPT of color at all. She suggests that while 'the visual semantics of English reflects a preoccupation with colour, that of Warlpiri suggests a preoccupation with things "shining" somewhere in the speaker's environment' (2008:413) or otherwise being visually salient or standing out—a non-chromatic emphasis in visually parsing the world. On this view, if Warlpiri speakers do indeed lack a concept of color, they lack a conceptual prerequisite for having color terms. Thus, what appear to be color terms in this language must in fact pick out some other aspect of visual experience (see also **Lucy 1997**).

This line of argument is supplemented by an examination of those Warlpiri words that are often taken to be color terms: **[End Page 888]**

> *yalyu-yalyu*, literally 'blood-blood'; *karntawarra-karntawarra*, literally 'ochre-ochre'; *yukuri-yukuri*, literally 'grass-grass'; *walya-walya*, literally 'earth-earth'; and *kunjuru-kunjuru*, literally 'smoke-smoke'. . . . The form of these words provides a clue to their meaning as it is understood 'from the native's point of view': they all appear to imply that what the speaker sees is likened to some prototype—blood, ochre, grass, earth, or smoke.
> (**Wierzbicka 2008**:410)

Specifically, Wierzbicka argues that these Warlpiri words do not single out colors per se, and certainly do not as a system constitute an abstract partition of the domain of colors—rather, these words merely denote general resemblances to particular substances with which speakers of the language are likely to be familiar in their day-today lives, with the chromatic element of that resemblance having no special status.

One response to this line of argument has been that even if Warlpiri does lack a word for 'color', Warlpiri speakers might still have terms for specific colors (**Kay & Kuehni 2008**). But this response leaves open the question of whether Warlpiri does in fact have color terms—that is, whether the contested terms in this language are comparable to color terms in other languages. We wished to address this open question.

We reasoned that if speakers of Warlpiri lack a concept of color, and if what appear to be color terms in their language instead pick out general resemblances to substances that happen to be familiar to speakers of the language, then there is no reason to expect the Warlpiri color-naming system to fit the structure of perceptual color space. If the alleged color terms of Warlpiri are indeed just that, however, we would expect to find a close fit between that color-naming system and the shape of color space.

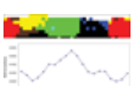

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Figure 4.
(top) The color-naming system of Warlpiri. (bottom) Well-formedness for Warlpiri when rotated 0, 2, 4, 6, etc. hue columns. The configuration that yields greatest well-formedness is the unrotated (attested) version.

To decide this question, we performed the rotation analysis described above on Warlpiri. The top panel of **Figure 4** shows the Warlpiri color-naming system, and the bottom panel shows the results of the rotation analysis. As in the case of Pirahã, the attested Warlpiri system exhibits greater well-formedness than any rotation of that system to any point along the hue dimension. In this sense, the Warlpiri system, like most languages in the WCS and the Sheldon data for Pirahã, fits the structure of color space, suggesting that the proposed color terms in Warlpiri may in fact be color terms. **[End Page 889]**

4. Karajá and waorani

We have seen that the color-naming systems of two languages that have been argued to not have color terms in any generally accepted sense in fact fit the structure of perceptual color space in a manner similar to that of many other languages. However, not all languages fit this pattern—there are genuine exceptions. We focus here on the two languages in the WCS for which a rotation analysis reveals the worst fit to perceptual color space: Karajá and Waorani.

Karajá is a Macro-Ge language of Brazil. It is one of two languages in the WCS that contains a term that includes yellow, green, and blue; the Karajá term *ãrè* also includes purple. The remaining terms, black, white, and red, are unsurprising. The color-naming system of Karajá is displayed in the top panel of **Figure 5**.

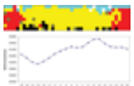

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Figure 5.
(top) The color-naming system of Karajá. (bottom) Well-formedness for Karajá when rotated 0, 2, 4, 6, etc. hue columns. The unrotated (attested) version does not yield greatest well-formedness.

The results of a rotation analysis on the Karajá data are displayed in the bottom panel of **Fig. 5**. Unlike Pirahã and Warlpiri, the attested Karajá data do not yield greater well-formedness than any rotated variant. Instead, the variant with greatest well-formedness is that at +10 columns rotation, which is quite different from the attested system. In this sense, the Karajá color-naming system does not fit the structure of perceptual color space. It differs substantially from what universal forces would predict.

Waorani is an unclassified language of Ecuador; its color-naming system is displayed in the top panel of **Figure 6**. Kay and colleagues (2010:542) describe Waorani color naming as follows:

> Waorani presents a unique situation. It is the only language in the survey and the only language known to the authors that contains one term covering both white and yellow and a distinct term covering red.

Kay and colleagues (2010) also mention that Waorani responses were variable. Despite this variability, however, and despite the unusual configuration of categories that Wao-rani presents, the overall pattern of Waorani color terms is neither random nor incomprehensible in terms of what has been observed regarding universal tendencies in color **[End Page 890]** naming. Apart from the inclusion of an extended yellow in the white term, Waorani conforms to a major widespread pattern, containing terms for white and light colors (including yellow, etc.), black and dark colors (including brown), red (including pink), and a composite green/blue category 'grue'.

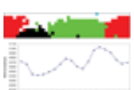

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Figure 6.
(top) The color-naming system of Waorani. (bottom) Well-formedness for Waorani when rotated 0, 2, 4, 6, etc. hue columns. The unrotated (attested) version does not yield greatest well-formedness.

The results of a rotation analysis on the Waorani data are displayed in the bottom panel of **Fig. 6**. Again, the greatest well-formedness is not that of the natural system, but instead that of the variant at +10 columns rotation. Thus, the color-naming system of Waorani, like that of Karajá, does not fit the structure of perceptual color space. Although neither Waorani nor Karajá has been regularly held up as a counterexample to universals of color naming, they both are genuine counterexamples—unlike the alleged counterexamples Pirahã and Warlpiri.

5. Conclusion

The color solid is a warped blob. Some hue-lightness combinations achieve greater saturation, hence presumably greater salience, than others. The resulting irregular landscape, coupled with simple principles of categorization, accounts both for universal tendencies of color naming, and for some deviation from those tendencies—thus reconciling the traditionally opposed 'universalist' and 'relativist' views of color naming (**Jameson & D'Andrade 1997**, **Regier et al. 2007**). The same shape-based perspective, we have argued here, can also illuminate which languages are genuinely exceptional in terms of color naming. Pirahã and Warlpiri have both been claimed to lack color terms; specifically, it has been claimed that what appear to be color terms in these two languages are not that. This claim fails to predict that the alleged color-naming systems of these two languages should fit the structure of color space well—yet they do fit it well, like the color-naming systems of most other languages. In contrast, no special status has been regularly claimed for Karajá or Waorani; yet their color-naming systems do not fit the structure of perceptual color space. We conclude that **[End Page 891]** there are indeed languages that deviate substantially from what universal forces would predict, but these are not the languages that have been proposed as such. We hope that this demonstration will help to place the observation that some languages deviate from universal norms in the context of the existence of those norms. We hope moreover that it will help to shift analytical attention to those languages that are genuinely unusual in their color-naming systems.

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[End Page 892]

Footnotes

1. To see this and subsequent figures in color, please see **http://linguistics.berkeley.edu/~regier/color-shape/** . The full article with the figures in color can be found online at Project MUSE; instructions for access can be found at **http://lsadc.org/info/pubs-lang-online.cfm** .