

## There is more than one level in color naming – A reply to Zollinger (1984)

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**Summary.** It is argued that the structure of the Munsell solid is not sufficient to explain the evolution of color terms as Zollinger (1984) has argued. A manifold model of color perception is described with a local metric structure of discriminability and a global categorical structure. This model elucidates the interdependency of the different levels of constraints on color naming and permits the integration of experimental results which cannot be explained in the model underlying Zollinger's (1984) color-metric argument for the emergence of 'turquoise'.

The major goal of Zollinger (1984) is to show how the structure of the color space (as defined by the Munsell solid) makes the evolution of the color category 'turquoise' necessary and how this evolution is fostered by technological and cultural developments.

The arguments regarding the latter point are exhaustive and convincing. However, the imputed process underlying the first point, namely, that the distance in the color space between focal blue and focal green is solely responsible for the evolution of turquoise as a new color category, does not appear to be adequate.

In my opinion, at least three levels of constraint on color naming can be distinguished and have to be accounted for by models for the generation of color lexica. The fact that constraints on different levels are interconnected may have led to the heated debate concerning universals and cultural relativity in perception (Brown & Lenneberg, 1954; Berlin & Kay, 1969; Rosch, 1974; Kay & McDaniel, 1978; Zimmer 1982).

The distinguishable levels of constraint are:

- (i) The physiological basis of color perception (see DeValois, 1973; Wattenwyl & Zollinger, 1979).
- (ii) General rules of cognition regarding the nature of basic versus derived color categories, the role of prototypes, and the formatting of internal representations (see Rosch, 1974, 1975; Kay & McDaniel, 1978; Zimmer, 1982).

- (iii) The communicative purposes in color naming which influence the 'implicatures' in conversation (Grice, 1975) and the determinacy of verbal meaning as the precondition for shareable knowledge about conditions of the world (e.g. colors) (Hirsch, 1967; Freyd, 1983). Furthermore there are specific linguistic constraints on complex concepts such as, for instance, metaphorical color names. These constraints can be semantic as well as syntactic (Cohen & Murphy, 1984).

From the universalist point of view, levels (i) to (iii) form nested sets with level (i) as the core. That is, the physiologically determined coding of light into opponent-color categories is primary and universal for all humans with non-pathological color vision. Furthermore, the rules for the mental representation of these categories are supposed to be universal, too: the formation of disjunctive categories (e.g. 'grue') or derived categories (e.g. orange) and the internal code (format) of the categories. In contrast, the position of strong cultural relativity claims that the communicative and linguistic constraints are central and that the character of other constraints is merely derived.

However, the results of Zimmer (1982) on the ontogenetic development of derived color categories, Kay & Kempton (1984) on the differences in the internal representation color caused by different color lexica, and Zimmer (in preparation) on the specifics of metaphorical color names, all indicate that at least levels (ii) and (iii) interact and that this, together with the failure of many investigators (e.g. Berlin & Kay 1969; Kay & McDaniel, 1978; Zimmer 1982) to make clear the difference between levels (i) and (ii), has made many experimental results inconclusive and has in general rendered the question of universalistic versus relativistic rules of perception so difficult to resolve.

Zollinger's claim that the distances between green and blue or between black and yellow make the evolution of 'turquoise' and 'brown' an immediate consequence of the architecture of the color solid is totally dependent on the role that spatial representations play in human information processing. Shepard (1982a) suggested that external objects (here: reflected light on objects A, B, C), proximal stimuli (here: colors as coded by the opponent-color process, A', B', C') and internal representations (A'', B'', C'') are related as in Figure 1.

Furthermore, he says: "The designation of the relation between corresponding internal and external structures as one of 'complementarity' attempts to capture these two aspects of that relation — namely: (a) that the two structures, existing in necessarily disjoint domains, cannot be directly compared; and (b) that they must nevertheless be capable of a very precise and efficient mesh at the lower-dimensional common boundary" (Shepard, 1982a, p 331). The mapping of the distal stimuli into mental representations has to be such that matching against the external object is rapid and finetuned to the relevant characteristics of the object. Furthermore, the internal transformations have to mirror those transformations in the external world which are relevant for the survival of the organism (e.g. color contrasts). This relationship makes it possible for objects in the external world to keep their identity in spite of transformations (the problem of constancies; see Høffding, 1891) and prepares the organism to respond optimally to ongoing events. If the model for the internal representation of colors were purely spatial, that is, in an analogical mode,

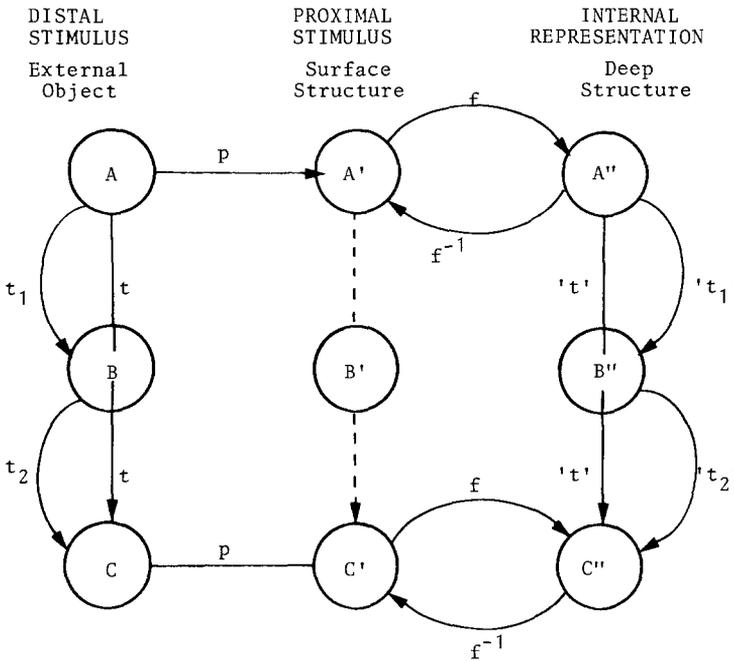


Fig. 1. Schema of the projective ( $p$ ), formational ( $f$  and  $f^{-1}$ ), and transformational ( $t$  and  $t'$ ) mappings between external objects (A, B, C), proximal stimuli (A', B', C') and internal representations (A'', B'', C''). The concatenation of transformations of external objects ( $t_1 \circ t_2 = t$ ) is the same as the concatenation of transformations on internal transformations ( $t_1' \circ t_2' = t'$ ) (in accordance with Shepard, 1982)

then neither the speed and accuracy of reactions to stimuli in different colors nor the phenomenon of color constancy could be accounted for. These and other effects (e.g. the illusory conjunction between colors and color names; Virzi & Egeth, 1984) have led to color vision being viewed as an example of categorical perception and to a corresponding (i.e. discrete) mode of internal representations being assumed.

In contrast to Kay & McDaniel (1978), Zimmer (1982) and especially Kay & Kempton (1984), Sun (1983) and Zollinger (1984) assume the mental representation of colors to be analogical. Sun (1983) computes the distances between color foci by using a weighted Euclidean distance function of the coordinates in the Munsell system. His further argument concerning a 3-wave model of the evolution of color terms is based on the assumption, that (i) the discriminability is constant in the whole Munsell solid; (ii) the local units of discriminability can be aggregated to global distances; (iii) these distances are distances in an analogical mental representation; and (iv) the distances are constant for all human observers independent of their color lexicon.

All of these assumptions are at least questionable (for (i) to (iii) see Shepard, Romney, & Nerlove (1972)). For the question as to whether these distances form a

standard against which the development of color terms can be pitted, assumption (iv) is of special interest. Kay and Kempton (1984) have shown that the perceived similarity of colors in the blue/green domain is systematically affected by the basic color categories of the subjects. In their experiments they compared the distances between color chips as judged by English-speaking and Tarahumara-speaking<sup>1</sup> subjects. The general result is that the lexical-category boundary of English-speaking subjects distorts the discriminability scale of colors as computed from the Wyszecki & Stiles tables (1967, pp 450–500).

This result makes it necessary to investigate further the relation between the format of the mental representation and the conversational and linguistic constraints.

Kay and McDaniel (1978), Zimmer (1982), and Kay and Kempton (1984) only make assumptions about the local discriminability of colors. Therefore, it is appropriate to use the physical scale (wavelength rescaled for equal discriminability; see Zimmer, 1982, Table 1) as the local universe of discourse. These local universes of discourse can be combined into a higher-dimensional configuration space (see Penrose, 1980).<sup>2</sup> The resultant manifold preserves the analogical character of color perception (in the local metric of discriminability) as well as its categorical character (in the configuration space).

This model elucidates that no cultural relativity can be found in discrimination tasks because of the close mesh between local discriminability and the corresponding physical variable. On the other hand, the effects of language on global color comparisons (Kay & Kempton, 1982), memory for colors (Brown & Lenneberg, 1954), or illusory conjunctions in color concept formation (Virzi & Egeth, 1984) indicate that the configuration space of colors is cognitively penetrable (Pyslyshyn, 1984).

The cognitive penetrability becomes especially obvious when primary color terms are compared to those derived color terms, the metaphorical character of which is still recognizable (e.g. 'turquoise'). Zimmer (in preparation) has found that:

- (i) In general, the meaning of these color terms is more restricted (see the steepness of the estimated membership functions for 'turquoise' and 'orange' in Zimmer, 1982).
- (ii) The range of color constancy for metaphorical terms is much smaller than for primary terms.
- (iii) The recognition of colors commonly described by metaphors is very accurate but much slower than for primary terms. Evidently, the generally found tendency to enhance the determinacy of a color lexicon by implementing metaphors makes the communication about small, but culturally important variations feasible (Hirsch, 1967; Freyd, 1983).

For these reasons it seems plausible to look for the mechanisms of color-term evolution on the level of general cognitive constraints and not in a generalized discrimination space. Actually, Zollinger's (1984) analysis that cultural and technological

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1 Tarahumara is an Uto-Aztecan language with only one verbal label (siyoname) for blue or green.

2 Shepard (1982) has applied this approach to the structure of musical pitch.

conditions are responsible for the evolution of 'turquoise' as a common color term supports this conclusion.

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