Color categories are culturally diverse in cognition as well as in language.

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The experimental studies reported here were partly supported by ESRC grant no. R000236750 to Davidoff, Davies & Corbett and by a University of Essex RPF award to the author. I am grateful to Jules Davidoff, Goldsmiths College, University of London and Ian Davies, University of Surrey, in collaboration with whom the main research reported here was carried out.

Abstract

Categorization is a fundamental property of human cognition. This article presents a summary of recent research that has re-examined the nature of linguistic and non-linguistic color categories and the relationship between them. Improvements in experimental paradigms combined with a better understanding of the relationship between physiology and higher-level cognition have led to a clearer understanding of the complexities of the relationship between culture, language, cognition and perception. It is concluded that possession of linguistic color categories facilitates recognition and influences perceptual judgments, even in languages with terms that are less abstract than English. Cognitive categories for color appear to be tightly tied to the linguistic terms used to describe them.

INTRODUCTION

Despite more than fifty years of investigation, the issue of whether, and to what degree, language might influence thought is still hotly debated. The domain of color categorization has been put forward both as an extreme case of linguistic influence on cognition (e.g. Brown & Lenneberg, 1954; Ratner, 1989) and the reverse – an instance of the complete independence of thought and language (e.g. Bornstein, 1985). A second, related, issue is the question of whether color terminologies 'evolve' naturally to an optimum point for communicative and descriptive purposes. This issue has been addressed in a number of studies (Berlin & Kay, 1969; Kay, Berlin & Merrifield, 1991; Kuschel & Monberg, 1974; Levinson, 1997) but is not considered here. Many languages have been documented to use additional 'borrowed' terms from other languages and all may rapidly expand their color vocabulary when first they come into contact with more technologically advanced cultures. Given the relatively fixed range of human color vision, there may also be optimal numbers of linguistic categories for different levels of description. The evidence put forward here leaves aside this question and seeks only to address the issue of whether speakers of any language can have more (and different) cognitive color categories than they have linguistic ones.

In a series of classic studies in the early 1970s, Rosch Heider (Heider & Olivier, 1972; Rosch Heider, 1972a, 1973, 1975a) found that a remote branch of a hunter-gatherer tribe, the Dugum Dani, seemed to show the same cognitive organization of color as speakers of American English despite using only two basic terms for the whole range of visible colors (but see Rosch Heider 1972b). Her results have been widely interpreted as clearly supporting the notion that a particular set of color categories might be pan-human cognitive universals that transcend terminological differences and might be innately specified (e.g. Rosch, 1975b; Bornstein, 1985; Soja, 1994). What this means is that it is possible to have differences between the "structure of the color space in memory" and the structure of the lexical categories used to describe them (Heider & Olivier, 1972, p. 351). In the case of a language with just two basic color terms, but a representational color space divided into eleven basic categories, the range of referents for each Dani term cut across the eleven representational categories (Heider, 1972a, table 2) “Heider concluded that the Dani shared universal focal colors, which aided their memories independently of language” (MacLaury, 1997, p.5). Since natural languages are widely considered to be “systems for the expression of thought” (Hurford, in press, p.2), such a disconnection between the two systems has serious implications for a wide range of disciplines and the evidence for it should be overwhelming.

However, Rosch’s original results may also be consistent with linguistic relativity (Saunders & van Brakel, 1997; Davies, 1997). Dani memory performance was extremely low compared to English speakers (5% vs. 28%), perhaps because the lack of lexical terms made the memory task extremely difficult. Moreover, recent findings, using a range of techniques, have broadly supported the tight links between language and thought in other fields. Gumpertz and Levinson (1997) found that lexical variations in number systems were mirrored by differences in numerical reasoning and both Levinson (1996) and Choi, McDonough, Bowerman and Mandler (1999) found similar results for cultures whose lexical terms for spatial relations differed. Malt and Johnson (1998) found that category judgments for artifact categories were made in line with lexical categories; a result also found for classification by material or shape by Lucy (1992), for time by Boroditsky (2001) and for modes of motion by Gennari, Sloman, Malt and Fitch (2002). Roberson, Davidoff and Shapiro (2002) also failed to replicate Rosch’s (1973) finding of universal categories of basic shape (square, circle and triangle), while Sera and colleagues (Sera, Berge & del Castillo Pintado, 1994; Sera et al., 2002) have reported differing effects of grammatical gender on classification across languages.

The weight of evidence in favor of tight links between culture, language and thought would thus appear to make color a unique field of classification, if cognitive color categories can truly be independent of the terms used to describe them. In the light of the accumulated evidence favoring a tight linkage between lexical and cognitive categorization of perceptual stimuli, Davies (1997, p.186) suggested that “the acceptance of color universals in psychology has a narrow empirical base. It rests largely on Rosch-Heider’s work with the Dani of Indonesia…important as her work is, the inferential load it is required to support is too heavy”. This article reviews some recent psychological research into the relationship between color terms and cognitive representation of colors, developmentally, cross-culturally and among native English speakers.

In developmental research the issue of color term acquisition has been repeatedly studied. Many people, including Charles Darwin (cited in Bornstein, 1985) have presumed their children to be color blind because they were unable to correctly apply color terms at a relatively late age, compared to their general linguistic competence. Research in this field has consistently demonstrated that all children acquire accurate color naming relatively late (Rice, 1980; Andrick & Tager-Flusberg, 1986; Mervis, Bertrand & Pani, 1995; Braisby & Dockrell, 1999). Children also have extraordinary difficulty in learning their first color term. Given a contrast task that makes learning additional category terms easy (Carey & Bartlett, 1978; Heibeck & Markman, 1987), two-year-old children who knew no color names, but hundreds of other names, took on average 800 trials simply to respond "red" to red objects and "green" to green objects (Rice, 1980). Sandhofer & Smith (2001) suggested that the delay in children’s color term learning reflects differences in adult linguistic input from other comparable concepts (such as size) although Pitchford and Mullen (2001) suggested that all abstract properties of objects (color, size, form and motion) show a similarly slow timescale of development.

These results are at odds with the research of Bornstein, Kessen and Weiskopf (1976), who found apparent adult-like categorization of colors in four-month-old infants (but see Werner & Wooten, 1985). Bornstein himself (1985) questioned why, if children have a set of universal categories that are present at birth, learning to map the appropriate terms onto those categories should be so difficult. A recent longitudinal study has sought to compare the development of color categories, over a three year period, in English speaking children with that of children of the Himba tribe, in northern Namibia, whose language has only five basic color terms (Roberson, Davidoff, Davies & Shapiro, in preparation). This study set out to address the central question of whether children who speak different languages come to the task from the same cognitive starting point (universal categories) and whether subsequent divergence happens only at a linguistic level or is apparent in non-linguistic tasks also. Ongoing studies are also re-visiting the infant findings of Bornstein, Kessen and Weiskopf (1976) and seeking to eliminate possible methodological artifacts.

In the period since Rosch's original work a number of new experimental paradigms have examined color categorization by adult speakers of English. These studies have included techniques of linguistic, psychophysical and cognitive measurement and a comprehensive review is beyond the scope of this article. Outlined here are a number of studies that have attempted to examine the relationship between linguistic (naming) cognitive (memory) and perceptual (similarity) measures.

Roberson, Davies and Davidoff (2000) investigated *Berinmo* naming and memory for a wide range of colors using highly saturated 'focal' samples (the best examples of English color categories), 'non-focal' samples (poorer examples) and low saturation samples (color blends with white). Berinmo are a hunter-gather tribe, and the group investigated resided in a remote, previously unstudied location, on the upper reaches of the Sepik River in Papua New Guinea. Experiment 1 attempted to replicate Rosch Heider & Olivier's (1972) experiment with the Dani. The accuracy with which Berinmo remembered colors bore a striking similarity to the Dani; this was poor for both groups of Melanesian subjects (9.6 and 7.7 respectively / 40). However, statistical analysis showed that, for both studies, the best statistical fit (lowest stress value) was between Melanesian naming and Melanesian memory; a finding consistent with the linguistic relativity hypothesis and not with the interpretation of the original study. Accurate recognition memory for desaturated colors did appear to mirror color vocabulary. Further experiments, investigating recognition memory and naming for saturated colors seemed initially to concur with Rosch's (1972) findings. However, when response bias was controlled, by randomizing the stimulus array, there was no recognition advantage for 'focals' over 'non-focals'. Paired-associate learning also failed to show any advantage for 'focal' stimuli. A similar result was also found by Jameson and Alvarado (in press).

The differences between English and Berinmo allow a further critical test of the contrast between color universals and linguistic relativity. Berinmo does not mark the distinction between blue and green, but it does have a name boundary (between 'nol' and `wor') in a color position that does not exist in English. In a further set of experiments, we investigated 'Categorical Perception' effects at the boundaries of both English and Berinmo linguistic categories (blue-green and nol-wor).

Over the past 10 years a number of experimental procedures have found evidence for Categorical Perception of color paralleling that found in speech perception (c.f. Harnad, 1987; Snowdon, 1987; Bornstein, 1987). Categorical Perception involves a many-to-one mapping from the physical to the perceptual dimension so that a continuum of physical stimuli with many just-noticeable differences is perceived discontinuously as a smaller number of discrete segments (Bornstein, 1987). The defining attribute of current models of Categorical Perception is taken to be a sharp peak in relative discriminability of stimuli at category boundaries compared to the poorer discriminability of items within categories (Harnad, 1987).

Categorical Perception, in the color domain, means that the physical continuum of the chromatic spectrum comes to be perceived as qualitatively discontinuous, discrete segments (red, orange, yellow, etc.). Distances between items from different categories (relative to some objective measure such as a just-noticeable-difference) are perceived as greater, while distances between items from the same categories are perceived as smaller (Bornstein, 1987; Harnad, 1987; Livingston, Andrews, & Harnad, 1998). Categorical Perception for color is manifest in that stimuli from the center of color categories are matched and classified faster than those at the edges (Bornstein & Monroe, 1980), discrimination of stimuli (Laws, Davies & Andrews 1995) and same/different judgments (Bornstein & Korda, 1984) are faster and more accurate across than within categories with similar effects in memory when there is a delay between the presentation of the stimuli to be matched (Boynton, MacLaury, & Uchikawa, 1989; Uchikawa & Shinoda, 1996). Harnad (1987) has suggested that if it can be shown that learned labels or descriptions influence enhanced discriminability at category boundaries, then Categorical

Perception would support the hypothesis that linguistic categories influence perception. However, if Categorical Perception were to be found independent of language then it would be evidence for the existence of perceptual category divisions at a deeper, or more primitive level.

The suggestion that Categorical Perception effects may not be independent of language is supported by findings that speakers of languages that do not make the same linguistic distinctions of perceptual continua, but instead perceive a continuously graded change (Kay & Kempton, 1984; Roberson, Davidoff & Shapiro, 2002). An examination of the breakdown of perceptual categorization in visual anomia also implicates language as the origin of the divisions within adult color and face categories (Roberson, Davidoff & Braisby, 1999). Categorical Perception effects have also been shown to selectively disappear when recognition tasks are carried out under conditions of verbal interference (Roberson & Davidoff, 2000). However, it has been shown that Categorical Perception can be acquired with training that does not include overt labeling for a variety of domains, including arbitrary color categories (Özgen & Davies, 2002) and lightness / size (Goldstone, 1994). Moreover, there is also evidence that Categorical Perception for colors may sometimes persist even when labeling is prevented (Pilling, Wigget, Özgen & Davies, 2002) or unavailable (Roberson, Davidoff & Braisby, 1999). Thus, while language may have a role in the establishment of Categorical Perception, it may not be necessary for its maintenance.

In the cross-cultural experiments of Roberson, Davies and Davidoff (2000) several different paradigms were used to investigate Categorical Perception, exploiting the different boundaries found between green and blue in English (absent in Berinmo) and 'nol' and 'wor' in Berinmo (absent in English). In one experiment, subjects were asked to remember a particular color over a 30 second interval and then select the same color from a pair of similar alternatives. When an incorrect choice was made it was sometimes from the same name category and sometimes from a different one. If stimuli are perceived categorically, then target recognition from a cross-category pair of stimuli should be more accurate than from a within-category pair. English subjects showed the predicted advantage for cross-category blue-green decisions but not for nol-wor decisions. Berinmo showed no sign of a cross-category advantage for blue-green stimuli while maintaining their cross-category advantage for nol-wor stimuli. Thus Categorical Perception occurs, but only for speakers of the language that marks the categorical distinction.

We also examined similarity judgments in an odd-man-out/matching-pairs triad task (Kay & Kempton, 1984; Fukuzawa et al., 1988; Laws, Davies & Andrews 1995). In such a task, where the subject is asked to examine three stimuli and decide which two samples are most alike, the matching pair could be chosen according to strict perceptual similarity. But they could also be chosen according to whether the members of the pair are named differently to the other item in the triad if two items come to seem more similar when they are given the same name. In this experiment speakers of both languages made judgments in line with their own color vocabulary more consistently than judgments relating to the other language. Indeed, both groups of subjects were at chance for decisions relating to the other language's color boundary with English speaking subjects particularly inconsistent with their choices that concerned the nol-wor boundary. These cross-lingual data are consonant with the stimuli being equidistant (in perceptual steps) and there being no category boundary to drive decisions in a particular direction (Kay & Kempton, 1984).

In a further experiment it was decided to investigate the possibility of teaching both English and Berinmo subjects new category divisions. Harnad (1987) noted that the real test of the scope and generality of Categorical Perception is the case of learning categories for which there is no specially prepared discontinuity, either in the nervous system or in the environment. English and Berinmo speaking populations were taught, with feedback, to sort sets of stimuli into two categories. English speakers were required to learn the nol vs. wor distinction or an arbitrary division of the green category, while Berinmo speakers learnt either the green vs. blue or the yellow vs. green distinctions. For comparison, all subjects were also required to categorize stimuli in a manner consonant with the color names of their own language.

Subjects learned to divide first one and then a second set of stimuli into two categories (determined by the experimenter) in training sessions separated by at least one week. Order of learning of the sets was counterbalanced across subjects. Subjects were instructed that they would be trained to sort a set of stimuli into two piles, one on the left and one on the right. Spatial locations were used rather than verbal responses ("X" is a "Y") to minimize the requirement for linguistic labels. Stimuli were presented one at a time and marginal examples of each category were included so that the learning task would not be trivially easy for speakers of the appropriate language.

English speakers (for whom there is an existing boundary between green and blue) find this division easier to learn than a new, arbitrary, division of the green category. Berinmo speakers, for whom neither of the boundaries exists linguistically, did not find the green-blue division easier to learn. For Berinmo speakers, the nol vs. wor division was easier to learn than the yellow vs. green boundary; for English speakers, this pattern was reversed. English speakers (for whom there is an existing boundary between green and blue) found this division easier to learn than a new, arbitrary, division of the green category. Berinmo speakers, for whom neither of the boundaries exists linguistically, did not find the green-blue division easier to learn. For Berinmo speakers, the nol vs. wor division was easier to learn than the yellow vs. green boundary; for English speakers, this pattern was reversed. These results support a tight link between linguistic labeling and cognitive categories.

In the set of experiments carried out by Roberson, Davies and Davidoff (2000) attempted replications of Rosch Heider's experiments found no evidence for universal basic color categories and a further set of Categorical Perception experiments showed positive evidence of the influence of linguistic categories on perception and memory for colors. Berinmo speakers, like those of all other languages hitherto investigated, appear to group contiguous areas of the color space together. However, no evidence was found for these sections to correspond to a limited set of universal basic color categories. It was concluded that possession of linguistic color categories facilitates recognition and influences perceptual judgments, even in a language whose terms are less abstract than English. A similar conclusion was reached by Kay and Kempton (1984) for English speakers, whose judgments of perceptual similarity they showed to vary depending on whether or not stimuli were named.

Adult speakers of different languages show different patterns of discrimination and memory for the same set of colors while their cognitive representations of color categories appear to be isomorphic with their linguistic categories. There are several ways in which such differences might arise. Either, as Bornstein (1985) suggested, all infants might be born with a particular set of cognitive color categories that are universal and innately specified (e.g. blue, green, yellow, red and possibly also pink, purple, brown and orange) and these might be over-written during development by those categories in current use within the infant's culture and language. In this case language learning would alter perceptual categories. Alternatively, as has been suggested by Lindsey and Brown (2002), exposure to UVB sunlight in equatorial regions might cause rapid yellowing of the lens and thus alter the color perception of older adults. In this case perception itself would alter and language descriptions would change in accordance. It is also possible that infants might simply perceive a perceptual continuum of just-noticeable-differences across the range of visible colors which they subsequently learn, through language, to categorize in a manner appropriate to their culture (Roberson, Davies & Davidoff, 2000), or that adaptation of the visual system may result from learned characteristics of the environment, because different observers experience different 'visual diets' (Webster & Mollon, 1997; Mollon, 2000).

There are a number of factors that favor some sort of learning explanation for color categories. Firstly, while the structure of the visual system clearly places limitations on the range of colors that can be distinguished, it need not prescribe the higher order categories into which they are divided. If infants were born with a particular set of color categories (those that are named in English), then it is hard to understand why English speaking children experience such difficulty and delay in learning to map color terms to existing concepts. Moreover, Karmiloff-Smith (1992) has suggested that infrahuman studies show such a degree of plasticity of cortical function in primates that, while the architectural mechanisms for categorization may be innate, the representational content cannot be.

If, on the other hand, cultural differences arise when a universal, innate set of categories change because adult perception of color is degraded by UVB exposure; then it is hard to explain the considerable number of languages that exist within equatorial latitudes and have a larger set of basic color terms (Berlin & Kay, 1969; MacLaury, 1987; Losche, 1982; Bromley, 1982; Bruce, 1984). If these linguistic differences can only be explained by differences in cultural practices among individuals suffering the same degree of UVB damage, the explanation becomes circular. If, however, human (and primate) visual systems are so ordered that a continuum of physical stimuli with many just-noticeable differences in hue, lightness and saturation is perceived and it is cultural salience, through language, that determines where the boundaries between color categories are set, then cognitive categories of color might be expected to vary cross-culturally to the same degree as linguistic categories. Moreover individual variation in color perception within a population would not necessarily lead to differential use of color terms.

However, this need not imply that color categories are arbitrary, that there are no constraints on categorization imposed by the structure of the visual system or that there are no universal principles of color categorization. No language has ever been reported to have a category that includes two areas of color space (e.g. yellow and blue) but excludes an area between them (green). There is no associative chain of similarity that could connect yellow to blue without passing through green. Grouping always follows principles of similarity (as defined by perceptual discrimination) and the only free parameter appears to be the placement of boundaries between categories. The grouping-by-similarity constraint appears to be strong even when the ability to categorize colors explicitly is lost in cases of color anomia (Roberson, Davidoff and Braisby, 1999). Moreover, when stimulus naming is inhibited, participants have often been shown to judge the similarity of perceptual stimuli in a continuous, rather than a categorical manner (Kay & Kempton, 1984; Roberson & Davidoff, 2000; Malt et al., 1999; Gennari et al., 2002; Pilling, Wiggett & Davies, 2002).

As an abstract dimension, color is a continuous variable. Color categories arise when the physical continuum of visible color comes to be perceived as qualitatively discontinuous, discrete segments (red, orange, yellow, etc.) (Harnad, 1987). Such categories may derive from the language of experience (Wierzbicka, 1990; Goldstone, 1994,1998; Malt, Sloman & Gennari, 2003) whether cultural or environmental. Color categories and the boundaries between them may be tied to the physical properties of the environment, rather than the physiological characteristics of the observer (Jordan & Mollon, 1995) and, at the same time, to the need to communicate about such properties Wierzbicka (1990). Goldstone and Steyvers (2001) have suggested that a critical component of any category learning is increased selective attentional weighting of salient dimensions. One example, for Berinmo speakers, might be that tulip leaves, a favorite vegetable, are bright green when freshly picked and good to eat, but quickly yellow if kept. Agreement over the color term boundary coincides with agreement over when they are no longer good to eat and is highly salient in a community that talks little about color. Language may be the agent that directs selective attention to the relevant stimulus dimensions for categorization.

There is sufficient current evidence to suggest both that color terms vary widely between different speech communities and that ‘visual diet’ also varies widely from equatorial rainforest to northern tundra. There may also be optimal levels of description of the range of visible colors (e.g. basic, subordinate, superordinate) for a range of purposes and levels of salience or expertise. However, the results of recent experimental research would suggest that there are no cognitive color categories that are independent of the terms used to describe them. Indeed the strategic use of verbal labeling for all visual stimuli may be such an automatic process that it is unavoidable even when participants remain unaware of its use. The question as to whether cultural differences in linguistic categories are driven by differing environmental experience, or differences in cognitive categories driven by differences in cultural salience of visual contrasts within that environment remains open. Current studies are reexamining the preferred segmentation of colors by infants as well as the cognitive organization of color categories in young children whose languages have different numbers of color terms in an attempt to address this issue in more detail.

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