Color Categories are not universal: Replications and new evidence from a stone-age culture

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Abstract

A series of experiments sought to replicate and extend the classic studies of Rosch Heider on the Dani with a comparable group from Papua New Guinea who speak Berinmo, which has 5 basic color terms. Her results have been interpreted as clearly supporting universal color categories. Some results could, however, be interpreted as supporting linguistic relativity. We investigated naming and memory for highly saturated 'focal', 'non-focal' and low saturation stimuli from around the color space. Recognition of desaturated colors did appear to reflect color vocabulary. When response bias was controlled, there was no recognition advantage for focal stimuli. Paired-associate learning also failed to show an advantage for focal stimuli. We further examined 'Categorical Perception' effects at the boundaries of both English and Berinmo linguistic categories. These were found, in both populations, only for existing linguistic categories. Whilst Berinmo speakers, like those of all other languages hitherto investigated, appear to group contiguous areas of the colour space together, no evidence was found for these sections to correspond to a limited set of universal basic color categories. We conclude that possession of linguistic color categories facilitates recognition and influences perceptual judgements, even in a language whose terms are less abstract than English.

A pioneering set of cross-cultural experiments (Rosch Heider & Olivier, 1972, Rosch Heider, 1972) were largely responsible for overturning the then widely-held view that color space could be arbitrarily "cut up" into different color name categories. The current view at the time was derived from the linguistic relativity hypothesis (Whorf , 1956). However, contrary to the Whorfian view, Rosch Heider argued that the perceptual / cognitive division of color space was universal. Rosch Heider's work was generally consistent with the proposal of Berlin and Kay (1969) that the emergence of color lexicons followed a predetermined evolutionary course. Thus, both the anthropological and psychological evidence pointed to an acceptance of universality.

Rosch Heider found that two populations with widely differing color vocabularies remembered colors in very similar ways that were not affected by differences in color naming (Rosch Heider & Olivier, 1972, Rosch Heider, 1972). These results were influential beyond issues of color representation and their evolutionary order of acquisition in promulgating prototype theories of categorization and are still of current concern (Roberson, Davidoff & Braisby, 1999). However, both Rosch Heider's original research, and the present studies concerned only the domain of color. Whilst the strength of the approach lies in its precision and control of the materials and experimental design, the conclusions drawn about universality are limited to issues concerning the effects of possession of different lexical terms on color perception and memory.

Rosch Heider's results have been widely accepted as proving the case for universal basic color categories but there are some potentially serious flaws in both the design and interpretation of her studies (Lucy & Shweder, 1979; Lucy, 1997b; Ratner, 1989; Saunders & van Brakel, 1997; van Brakel, 1993). In particular, the tasks which Rosch devised were extremely demanding and Dani performance on them was very poor.

In the intervening years, cross-cultural research on color (e.g., Kay et al., 1991) has largely concentrated on mapping the color space of different vocabularies rather than comparing naming and memory; only a few studies have attempted to address questions of linguistic influence on color categories

(Davies & Corbett, 1997; Davies et al, 1998; Kay & Kempton, 1984). Despite the equivocality of some of her results and the call for such research (Gellatly, 1995, Davies, 1997), no direct replication of Rosch Heider's work with the Dani had previously been carried out.

As no other culture has since been found to have as few as two basic color terms, in the present investigation, native English speaking subjects were compared to monolingual Berinmo speakers from three villages in Papua New Guinea whose language contains five basic color terms.

Although the Berinmo language was clearly at a more advanced stage of color vocabulary development than the two-term stage described by Rosch Heider for Dani subjects, it was nevertheless considered that Berinmo color vocabulary was sufficiently limited and that color, as an attribute of objects in their natural world, was of sufficiently little salience to make them a suitable target population on which to attempt a long overdue replication of Rosch Heider's most important original studies.

Color Naming

The Dani studied by Rosch Heider & Olivier (1972) were reported as a two-term language (light/warm and dark/cool). With five terms that classify as basic, Berinmo would be classified at stage IV(.G/Bu) on the revised Berlin & Kay list (Kay et al., 1997). The relevant linguistic checks were carried out to ensure that these terms were used adjectivally to describe the color of a variety of natural objects, rather than just as object terms (see Berlin & Kay, 1969 for a definition of 'basic color term'). Kay et al. list this stage combination as White, Black, Red, Yellow and Green/Blue. Even the surprising extension of the Berinmo term kel ("black") up through light purple is found in similar languages (Kay & Berlin, 1997) (see figure 1).

However, although the Berinmo pattern of naming is similar to many languages in the World Color Survey, (Kay, personal communication), to suggest that the Berinmo have the equivalent of five English categories seems uninformative. In fact, the Berinmo wor category encompasses some green, the nol category encompasses much of green, blue and blue/purple, wap covers almost all of the lightest colors and kel covers almost all dark colors.

Experiment 1

A cross-cultural comparison of naming and memory for desaturated colors.

Experiment 1 sought to replicate the study of Rosch Heider and Olivier (1972). They reported that speakers of a language with only two color terms made confusions in memory that were similar to those of English speaking subjects rather than based on their own color names. Therefore, Rosch Heider and Olivier argued, there must be a single underlying universal pattern of organization of the internal color space irrespective of the number of linguistic color categories. Rosch Heider and Olivier's (1972) data were equivocal, in that the results of the statistical and visual scaling procedures did not concur. In a replication study with 22 Berinmo speakers the results were unequivocal, the patterns of naming and memory within the Berinmo culture were significantly more similar than the patterns of memory between two different languages. However, the overall memory accuracy of Berinmo speakers bears striking similarity to those for Dani subjects (Rosch Heider & Olivier, 1972) despite the difference in the number of color words in the Berinmo and Dani vocabularies. Speakers of both Melanesian languages show much poorer performance on color recognition memory tasks than English speakers. The poor memory performance of Melanesian subjects could be explained if they relied on naming with an inadequate number of terms to meet the task requirements.

Experiment 2

An examination of the superiority of 'focal' colors in short-term memory

Rosch Heider (1972) showed superior recognition in short-term memory for focal colors than for non-focal colors by both Dani and American subjects. Focal chips were those designated by Rosch Heider as best exemplars, for English speaking subjects, of each of the eight chromatic basic color categories. Non-focal chips were chosen from areas in which no chip had been designated as best exemplar of a basic color term in any language.

There are reasons for doubting the advantage found by Rosch Heider for focal colors. The overall performance of Dani subjects was much poorer than that of American subjects (they recognized a mean of only 2/8 of the focal stimuli). Thus, whatever 'inherent salience' the focal items had, it was not

sufficient to ensure good recognition. Also, Lucy and Shweder (1979) demonstrated that Rosch Heider's test array made 'focal' chips more easily discriminable than other chips and that this, rather than their universal salience, accounted for their apparent superiority in memory. Subsequent experimenters (Garro, 1986; Lucy & Shweder, 1979, 1988) all used a modified and randomized array for testing. So, replication using the original array had never been undertaken.

30 monolingual Berinmo speaking subjects and 30 native English speaking volunteers participated in the initial replication. The results of this experiment were superficially similar to those found by Rosch Heider (1972) with Dani subjects. Although Berinmo speakers, like Dani, recognized few targets, they behaved like English speakers in that focal chips (representing the best examples of the 8 English chromatic basic color categories) were significantly better remembered than both sets of non-focals. However a more detailed analysis of the present data highlighted a concern raised by Rosch Heider and Olivier about the advantage for focal chips: the possibility that it might arise from a biased tendency of subjects to guess focal colors when they were unable to recognize target chips. In the present study, unlike that reported by Rosch Heider and Olivier, there was a significant tendency on the part of Berinmo subjects to choose focal stimuli in error for non-focal targets; consequently, the advantage for focal targets for Berinmo subjects disappeared when response-bias was taken into account. That some focal stimuli might have enhanced discriminablity within that particular layout of the stimulus array, (leading them to be frequently selected in error) as suggested by Lucy & Schweder (1979), was subsequently confirmed experimentally by asking a group of subjects to match each target item within the array while it was still visible. In a modified memory paradigm using Lucy & Schweder's (1979) randomised stimulus array, no memory advantage for focal stimuli was found for Berinmo speakers.

Experiment 3

Paired-associate learning of 'focal' and non-focal colors to words.

One of the strongest pieces of evidence for the universality of the 8 basic chromatic categories is Rosch Heider's (1972) demonstration that Dani subjects, whose language contained only two basic color terms, learnt paired-

associates faster to focal than to non-focal stimuli. Rosch Heider taught Dani subjects verbal paired-associates to the eight focal and eight of the non-focal stimuli used in previous experiments. In the first attempted replication of this experiment only 2/12 subjects reached criterion, whilst another 10 subjects failed to complete 5 days of training.

The failure of almost all subjects to reach criterion, and the high drop-out rate of this experiment made it difficult to conclude that there had been a non-replication of Rosch Heider's (1972) finding. However, analysis of the error data from subjects who completed the 5 days of training showed no advantage for focal over non-focal targets within this paradigm. The experiment was modified in the hope of finding a simplified paired-associate learning task that subjects would be able to complete to criterion within a reasonable period of training. In modifying the paired-associate learning task, the number of pairs to be learned was reduced from 16 to 8, with each subject learning paired-associates to 4 focal and 4 non-focal targets. Also, since the learning of verbal paired-associates might be particularly difficult for subjects with no formal education, a more concrete and culturally relevant set of pictures of palm nuts was used, all of which can be found in the New Guinea region. Each subject was given different pairings of nut pictures with target stimuli.

Under these conditions, welve monolingual Berinmo speakers were able to learn the stimulus set to criterion within the 5-day training period. However, there was no evidence for the superior learning of focal colors reported by Rosch Heider (1972). Although the order of learning of the focal set was close to that reported by Rosch Heider, as were the mean number of errors overall, it seems that subjects in this experiment learnt pairings in an apparently random manner.

Experiments 3a and 3b provide no support for the claim that focal colors become associated with color names more rapidly than non-focal colors.

In the present set of experiments there was no evidence from either short-term memory or long-term learning to indicate that Berinmo speakers have underlying perceptual and cognitive organization of color that favors the foci of the 8 English basic chromatic color categories. If it is the case that

patterns of recognition memory and learning reflect underlying cognitive organization, then the present results would indicate that for Berinmo speakers color memory is also isomorphic with their own linguistic categories.

The failure to replicate much of Rosch Heider's groundbreaking research leaves considerable doubt about her conclusions that color categories are universal. Further research could have extended replication to cover other languages with limited color vocabularies. However, though there is considerable need for such research, it was also possible to continue investigations with Berinmo by asking different questions concerning color categories. These investigations asked whether Berinmo color terms affect their perception and memory and whether they showed any incipient tendency to divide color categories along the lines predicted by evolutionary theory (Kay et al., 1997; MacLaury, 1997a).

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 for color is manifest when 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 judgements (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 et al, 1989, Uchikawa & Shinoda, 1996).

Harnad (1987) suggests that to the extent that it can be shown that the enhanced discriminability at category boundaries is influenced by learned labels or descriptions, then categorical perception would support Whorf's

original (1956) hypothesis concerning the influence of linguistic categories on perception; linguistic relativity would stand proven. However, if Categorical Perception were to be found independent of language then it would be evidence for the existence of (possibly universal) perceptual category divisions at a deeper, or more primitive level.

Experiment 4

Similarity judgements: Method of triads.

Experiment 4 took advantage of the different positions of category boundaries in English and Berinmo. English has a category boundary between blue and green whereas Berinmo has a category boundary between nol and wor. If categorical effects are restricted to linguistic boundaries, then the two populations should show markedly different responses across the two category boundaries. If categorical effects are determined by the universal properties of the visual system, then both populations should show the same response patterns. We examined similarity judgements in an odd-man-out/matching-pairs triad task (Kay & Kempton, 1984; Fukuzawa et al., 1988; Laws et al, 1995).

The judgements of eight monolingual adult Berinmo speakers and 8 adult native English speakers (all with normal colour vision) were examined and the data clearly show that linguistic boundaries affect similarity judgements. Speakers of both languages make judgements in line with their own color vocabulary more consistently than judgements relating to the other language. Indeed, both groups of subjects were at chance for decisions relating to the other language's color boundary.

Experiment 5 – Category Learning

Experiment 5 asked whether learning would be more influenced by the suggested predisposed perceptual discontinuities or, alternatively, more by existing linguistic discontinuities.

Seventeen monolingual Berinmo speakers and 17 native English speaking volunteers (from a non-undergraduate population) took part in the experiment. Seven subjects from each language group were asked to learn to divide a set of stimuli into either green vs blue and green 1 vs green 2 category splits; ten different subjects from each group learned the nol vs wor and yellow vs green category splits.

The comparison of learning rates of the green vs blue and green 1 vs green 2 category divisions clearly shows that 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, do not find the green-blue division easier to learn. For Berinmo speakers, the nol vs wor division is a category boundary that is easier to learn than the yellow vs green boundary; for English speakers, this pattern is reversed. The present results clearly add further evidence in support of a linguistic basis for color categorization.

Experiment 6

Two-Alternative, forced-choice recognition memory judgements

Categorical Perception in the present experiment was investigated in a 2-alternative, forced-choice, recognition memory task using an X - A,B design (Etcoff & Magee, 1992; Calder et al,., 1996; Young et al., 1997). In their design, a subject is first shown a target stimulus and then shown two consecutive test stimuli (A & B) and asked to decide which of the two matches the target. Categorical Perception is observed when subjects show increased accuracy in the discrimination of cross-category pairs of stimuli over within-category pairs. This paradigm was used to investigate, for the two boundaries, whether English and Berinmo speaking subjects would show differential recognition for the two sets of stimuli (that ranging from green to blue and that ranging from nol to wor). In experiment 6, the two stimuli A & B were shown simultaneously side by side rather than sequentially. In previous experiments, with normal English and language impaired subjects (Roberson et al, 1999, Roberson & Davidoff, in press), this had proved a reliable method for demonstrating Categorical Perception advantages for cross-category pairs of stimuli over within-category pairs.

Data from sixteen monolingual adult Berinmo speakers and 8 adult native English speakers revealed a significant difference between the two populations in terms of the memory for stimuli that cross category boundaries. While English speakers show these hallmarks of Categorical Perception significantly at the green-blue boundary but not at the nol-wor boundary, Berinmo speakers significantly show the reverse. These results

would seem to indicate that Categorical Perception is, indeed, the result of cultural and linguistic training rather than of underlying universal perceptual segmentation.

Our present results demonstrated, in a variety of tasks with quite different instructions, that Categorical Perception was consistently more closely aligned with the linguistic categories of each language than with underlying perceptual universals. Experiment 4 investigated color perception (compare Kay & Kempton, 1984; Davies et al., 1998), Experiment 5 required subjects to learn color categories and Experiment 6 required the short-term memory for a color sample. All our data show performance that is linguistically relative. Furthermore, in this second set of tasks, the performance of Berinmo speakers was not always poorer than that of English speakers.

General Discussion

In the present series of experiments a group of individuals were tested whose language contains five terms which are used consistently and with consensus to describe the color of a variety of objects in their environment. These terms met all the criteria laid down by Kay et al. (1991) for 'basic colour terms'.

Our data show that the possession of color terms affects the way colors are organized into categories. Hence, we argue against an account of color categorization that is based on an innately determined neurophysiology. Instead, we propose that color categories are formed from boundary demarcation based predominantly on language. Thus, in a substantial way we present evidence in favor of linguistic relativity.

These findings do not presuppose any neurophysiological properties of the visual system or a particular 'internal color space' beyond the broad assumption that some internal representations of concepts are (universally) necessary for any individual to make a judgement about whether a given stimulus is or is not a particular colour. Nothing in the present set of experiments would address the question of whether the speakers of different languages have similar or different organisation of their internal representations of color, although checks on the linguistic usage of terms can verify that they are used to refer to properties of objects in a similar manner.

However, were the relationship between language and thought to be so different between cultural groups that they constituted different language instruments it is unlikely that the tasks described here could be understood and carried out by different language speakers.

It is important to stress that the argument made here for color categories being a function of cultural experience and only, at most, loosely constrained by the default neural organization does not lead to an open-house. There are, indeed, constraints on color categorization linked to the properties of the visual system. The most important constraint would be that similar items (as defined by perceptual discrimination) are universally grouped together. Thus, no language would exhibit categories that include two areas of color space but excludes an area between them. The grouping-by-similarity constraint appears to be strong even when the ability to categorise colors explicitly is lost as occurs in color anomia (Roberson et al, 1999). Grouping by similarity can explain (for example) why there is no composite category that includes yellow and blue but excludes green. There is no associative chain of similarity that could connect yellow to blue without passing through green.

Color categories arise only when two similar items become qualitatively dissimilar; these boundaries derive from the language of experience (Wierzbicka, 1990; Goldstone, 1998). Goldstone (1998) suggests that the development of perceptual categories entails at least one, and possibly all, of three processes: the sensitization of category-relevant dimensions, the desensitization of category-irrelevant dimensions and/or the selective sensitization of relative dimensions at the category boundary. While there may be an innate predisposition towards the sensitization of some dimensions over others there is also room for plasticity. Thus, we conclude that there is an extensive influence of language on color categorization. The influence is deep rather than superficial applying both to perceptual and memorial processes.

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Figure 1a. Mean distribution of basic color terms by English speakers for the 160 chip Munsell array, with dots indicating the best examples for each color category as reported by Rosch Heider (1972).

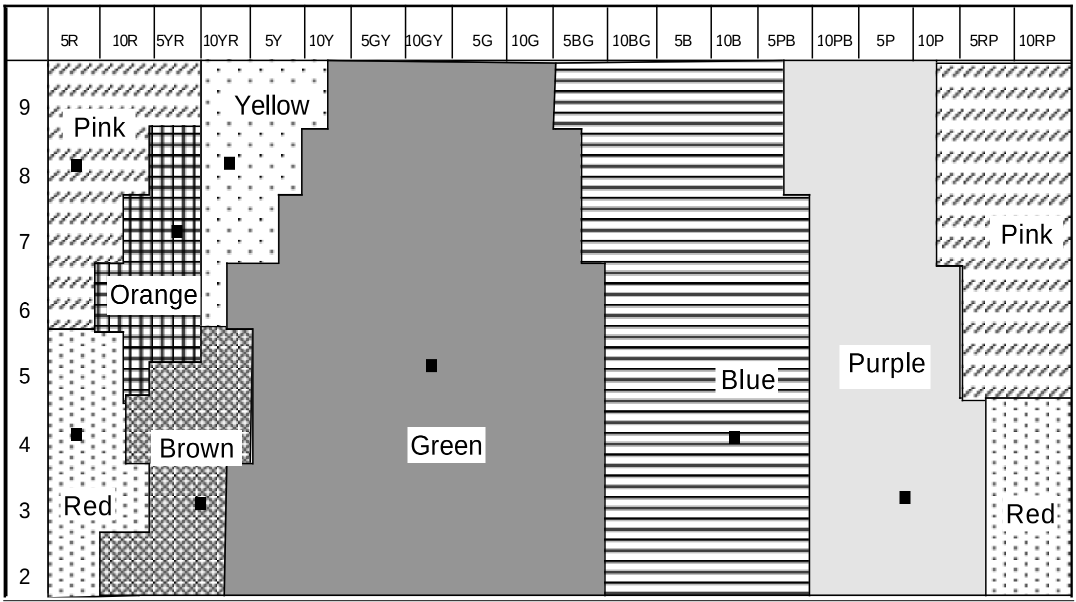

Figure 1b. Mean distribution of basic color terms by Berinmo speakers for the 160 chip Munsell array, with numbers indicating the number of individuals / 25 who chose a particular chip as best example of the category.