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Language and perceptual categorisation

Jules Davidoff

In a pioneering set of experiments, Rosch investigated the colour processing of a remote traditional culture. It was concluded that colours form universally natural and salient categories. However, our own cross-cultural research, backed up by neuropsychological data and interference studies, indicates that perceptual categories are derived from the words in the speaker's language. The new data support a rather strong version of the Whorfian view that perceptual categories are organized by the linguistic systems of our mind.

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Why do category members belong together? Or, put another way, why are category members seen as similar and different from members of other categories? For most categories, it can be concluded that the answers to these questions are determined by theories about the world, rather than perceptual similarity between category members[1]. However, for perceptual categories (e.g. colours, facial expressions) the role of perceptual similarity in establishing categories seems more plausible. I will argue that though plausible, it is not perceptual similarity, but rather linguistic similarity that is the critical factor in perceptual categorisation. It has also been argued, in the case of colour, that there are underlying, universal, neurophysiological mechanisms determining categorisation[2,3]. I will argue against that view. The arguments in favour of language will draw on neuropsychological and cross-cultural research; these will be reinforced by results from interference studies.

Colour categories are not innate

The proposal for universal colour categories[2] is held to gain strength from the known properties of wavelength-sensitive neurones[4]. Based on the opponent-process mechanism of neurones in the lateral geniculate nucleus and in V1, it was argued that there are two elemental achromatic categories (black, white) and four elemental colour categories (red, green, yellow and blue)[3,5,6]. The four colour categories are held to form around natural foci that produce uniquely red, green, yellow and blue sensations. The argument is based on the finding that there are two wavelengths for which opponent-process neurons termed R–G give no output[4]. Similarly, there is a wavelength that corresponds to no output from the other type of opponent-process neurones, termed Y–B. However, the respective wavelengths chosen to correspond to the typical or unique colours of blue, yellow and green do not consistently match the predictions from neurophysiology[7]. In fact, it ought to go without saying that no firm conclusion concerning neurones could really be drawn by asking a person who already has the concept of blue, yellow or green to indicate a colour that is uniquely blue (or yellow or green). Furthermore, the unique colours produced by colour-blind observers do not tally with the predictions made from their altered retinal output[8]. In fact, the neurophysiological data show that neurones simply respond selectively to particular wavelengths[9], or to combinations of wavelength and brightness[10]. Such selectivity is insufficient to allow that the neurones act

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in a categorical manner. There is no evidence that neurones respond selectively to any of the four basic colours, let alone selectively to those that we might call purple, brown, and so on.

Perceptual categories cannot be based on observation

Before considering the empirical evidence, I will outline the philosophical stance that observation alone can never produce perceptual categories. Consider colour concepts: for colour, it might seem obvious that observation would be enough to answer the simple question as to why two 'reds' look like each other, whereas a 'red' and a 'yellow' do not. However, colour categories are not supported by a direct and simple relationship with similarity[11,12]. If colour concepts were based solely on observation they would lead to a paradox – the so-called 'Sorites paradox'.

'...so as not to be trapped in the [Sorites] paradox, we require a non-perceptual mechanism to form categories.'

For example, take the case of a series of colour patches of decreasing wavelength, each of which is indistinguishable from its immediate neighbours because the steps in wavelength are below threshold for the human visual system. One end patch, it is agreed, can be called 'red'. If red is a truly perceptual or observational category then the immediate neighbour of this patch must also be called 'red'. But, so by extension must its immediate neighbours. Pursuing the reasoning, one arrives at the paradoxical conclusion that all colours in the series (even 'blues' at the other end) must be called 'red'. Thus, so as not to be trapped in the paradox, we require a non-perceptual mechanism to form categories. I shall argue that the mechanism is language. However, even if one were inclined to dismiss the Sorites paradox as a pseudo-problem based on unwarranted assumptions about thresholds[13], one would still need to account for the neuropsychological evidence. Patients with language impairments caused by brain damage behave as if the Sorites paradox is a reality[14].

Neuropsychological evidence

Brain damage that produces language impairments makes perceptual categorisation, including colour categorisation, very difficult[14,15]. We recently examined such a patient (L.E.W.) with normal colour vision who had no difficulty in recognising and interacting with objects[15,16]. His comprehension was generally excellent[16]. However, L.E.W. had marked difficulties with all types of spoken output. With respect to colour, he could not name or comprehend colour names, and experienced great difficulty in sorting colours into groups; for facial expressions there were similar problems (Box 1). His performance was marked by an adherence to pair-wise similarity comparisons. As consideration of the Sorites paradox shows, this would, and indeed did, lead him to group colours and facial expressions in a way that could be considered paradoxical or incoherent. L.E.W.'s sorting was exactly like that Goldstein[14] proposed to be an inevitable consequence of what is now called anomic aphasia. These patients, according to Goldstein, do not have an abstract attitude towards sorting tasks, but are driven by concrete associations. For example, one of his patients categorised a hammer with a saucepan because both were to be found in his kitchen. For colours, such associations are minimal. So, lacking an abstract attitude, L.E.W. is forced to sort by perceptual similarity and thereby reveal no effects of category boundaries.

Cross-cultural evidence

Original studies

Colour categories have played an important role in determining the theoretical structure of concepts. Rosch's analysis[17–19] helped mark the first shift away from defining-attribute theories of concepts (classical theory) to characteristic-attribute theories (prototype theory)[20]. Furthermore, Rosch's seminal work claimed a universal rather than language-based aspect to colour categories because of the cognitive similarities between languages with few colour terms and English[21,22]. The view prior to Rosch's work was derived from the linguistic relativity hypothesis of Whorf[23], who said that 'We dissect nature along lines laid down by our native language' (p. 231). However, contrary to the Whorfian view, Rosch argued that the perceptual or cognitive division of colour space was universal.

Rosch's cross-cultural investigations of colour categories compared naming and memory for colours between an American English population and a Stone-age agricultural population in Irian Jaya (the 'Dugum' Dani). The 'Dugum' Dani subjects (hereafter called Dani) were reported by K. Heider[24] to have only two basic[2] colour terms. In the first of her seminal experiments, Rosch found that the two populations with widely differing colour vocabularies remembered colours in very similar ways that were not affected by differences in colour naming[22]. In two further critical experiments[21], she also found that despite having only two colour terms, the Dani found it easier to recognise and learn the 'foci' (best examples) of the eight basic chromatic categories of English[2]. Thus, her cross-cultural research showed evidence of superior learning and memory for focal colours by subjects who did not code the categories linguistically.

Rosch's results have been widely accepted as proving the case for universal basic colour categories, but some potentially serious flaws have been pointed out in both the design and interpretation of her studies. In the first experiment[22], two different measures, both based on multidimensional scaling of

Box 1. Categorising facial expressions

There are a limited number of facial expressions[a], and these are perceived as categories[b–d]. Sorting facial expressions was examined in L.E.W., a patient with good comprehension but with much reduced speech output[e]. He showed a marked difficulty in sorting colours and facial expressions. To test his ability to sort facial expressions, we used pictures taken from Ekman's work[a]. His work had suggested that photographs of emotional expressions were universally recognized, though there is clearly considerable cultural intervention[f]. The photographs were morphed to obtain a continuous change from fear, to happiness, to anger[b,c]. The morph procedure gave 15 equal-interval steps. L.E.W. tried to do these perceptual categorisation tasks by putting together identical items. As there were no such items, he assessed the item that was perceptually most similar to the first one he had chosen. With colours that vary in brightness and saturation, and facial expressions that are multidimensional, perceptual similarity is difficult to assess. Hence, L.E.W. put together items from the different facial-expression categories (Fig. Ib). L.E.W. did not spontaneously realize that he was in error, although he was often unsatisfied with his final choices. However, allowing more time did not help him to correct his errors; he simply made different ones. His inability to perform the task was profound, as shown by the fact that he gained no benefit from having previously watched a correct sort (as in Fig. Ia).

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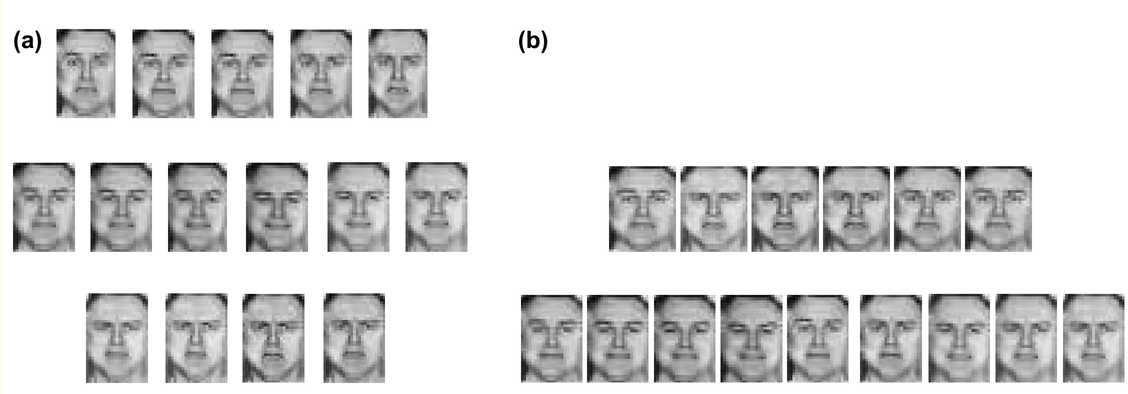

Fig. I. Sorting facial expressions into categories. (a) A control subject sorted the array of 25 facial expressions into categories of fear, happiness and anger (top to bottom). (b) L.E.W. was unable to sort the faces into categories; instead, he attempted to find the face that was perceptually most similar to the one he had just chosen.

the same data set, gave conflicting results. A graphical demonstration supported the view that colour categorisation is universal, but a statistical measure suggested that speakers of different languages organize their perceptual or cognitive categories in line with their different linguistic codings. The graphical result (that supporting the universalist view) was accepted, but no proper explanation was given of why the statistical analysis of the data failed to support this interpretation. For the second and third studies[21], Rosch's interpretation is weakened by the extremely poor performance of Dani speakers on these tasks.

In light of the concerns about the interpretation of Rosch's data, we attempted to replicate those three experiments. No other culture has since been found to have as few as two basic colour terms; indeed, Rosch[25] casts some doubt as to whether the Dani might have had as few as two basic terms. In the present investigation, native English-speaking subjects were compared to monolingual Berinmo speakers (see Box 2) from three villages in Papua New Guinea, whose language contains five basic colour terms. We were unable to repeat her findings[26,27]. Furthermore, new experiments further weakened the case for universal colour categories.

Categorical perception

Our new experiments made use of a property of categories that is known as 'categorical perception'[28]. Categorical perception gives rise to the following phenomenon: stimuli from the centre of categories are

Box 2. Colour naming

There are two types of colour naming. We can name the colours of objects or we can name colours independently of objects[a]. These types of colour naming dissociate in brain damage[b]. Both naming the colours of objects[c] and putting the correct name to a colour patch[a,d] are difficult tasks for young children, though evidence has been presented for colour categories in babies[e]. Many languages are also surprisingly deficient in colour names. The colour naming of English speakers and that of the Berinmo from Papua New Guinea are illustrated in Fig. I. To obtain these colour names, participants are shown individual Munsell chips, and are asked to give a colour name in one word. The Munsell system is used because adjacent steps in the system were calibrated to be of equal magnitude[f]. Rosch used the same procedure in her studies[g]. The Berinmo need only five words for the whole of the Munsell colour space[h]. The Berinmo terms are abstract, but all the terms do have an initial reference to natural objects. The boundary between these colours was used to show the effects of categorical perception[i]. The colours within these regions look more similar to the Berinmo than they do to us; therefore they find within-category decisions harder and cross-category decisions easier than UK participants.

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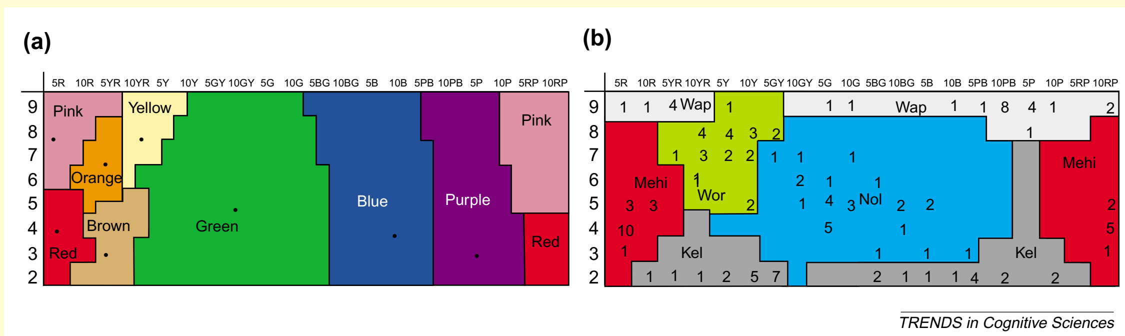

Fig. I. Colour naming. The distribution of colour names for a 160-chip Munsell saturated array given by (a) English speakers, and (b) Berinmo speakers from Papua New Guinea (see text for details). Adapted from Refs g,h.

classified faster than those at the edges, and consequently discrimination of stimuli is better across than within categories. Our results with Berinmo and English speakers demonstrated, in three tasks with different instructions, that categorical perception was consistently more closely aligned with the linguistic categories of each language than with the putative underlying perceptual universals[3,21].

The first experiment (see Kay and Kempton[29]) showed that when making similarity judgments between a group of three stimuli, observers judged two stimuli from the same linguistic category to be more similar, even though perceptual distances between each pair of stimuli were held equal. However, for those who made no linguistic distinction between these categories, no reliable tendencies were observable in similarity judgments. Thus, English speakers showed categorical perception for stimuli across the green–blue boundary, but not for those across the 'nol–wor' boundary (see Box 2). The reverse was true for Berinmo speakers[27].

The second experiment was on category learning. Participants from the two populations again showed a dissociation between categories that they did or did not distinguish linguistically. For English-speaking subjects, the division between green and blue was easier to learn than an arbitrary division of the green category, and the division between yellow and green was easier to learn than the division between the Berinmo colour categories of nol and wor. For the Berinmo, there was no difference in difficulty between learning the green–blue division and learning the arbitrary green division; however, the nol–wor division was significantly easier to learn than the yellow–green division[27].

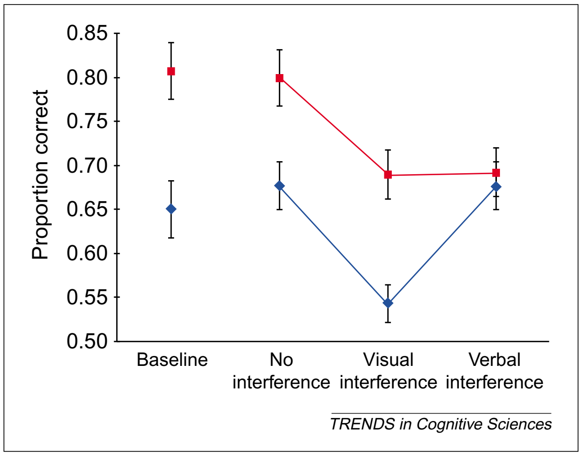

Fig. 1. Recognition of colours under interference. A short interval between presentation of target and test stimuli was filled with either visual or verbal interference. Both types of interference reduce recognition accuracy, but only verbal interference removes the cross-category advantage. The baseline represents performance without a delay. Red symbols, cross-category identification; blue symbols, within category identification. Reproduced, with permission, from Ref. 34.

The third experiment demonstrated an effect of linguistic category, but this time in recognition memory. English speakers showed significantly superior recognition for targets from cross-category pairs than for those from within-category pairs for the green–blue boundary, but not for the nol–wor boundary. Berinmo speakers showed the opposite pattern; they recognised significantly more targets from cross-category pairs than from within-category pairs for the set of stimuli crossing the nol–wor boundary, but not for the green–blue boundary[27].

Put together, these three new cross-cultural studies suggest that categorical perception shows the influence of language on perception. At the very least, our results would indicate that cultural and linguistic training can affect low-level perception, as suggested by Goldstone[30]. However, more than that, the results uphold the view that the structure of linguistic categories distorts perception by stretching perceptual distances at category boundaries[28,31]. It would appear that the internal colour space[32] is not static; some distances within it are 'stretched' or 'distorted' by the influence of linguistic categories.

Interference studies

With the constraints on experimental design required to work with Berinmo, experimental intervention was not possible to verify whether an essentially verbal code might underlie categorical perception. However, verbal suppression paradigms (see also Hermer-Vazquez *et al.*[33]) have been applied to native English speakers with results in accord with a verbal code[34] (Fig. 1). In the study, the advantage for cross-category judgments was examined in the same recognition-memory paradigm used with the Berinmo[27]. Only verbal interference removed the cross-category advantage. Similar results were obtained with the facial expressions shown in Box 1.

Constraints on language as the determiner of categorisation

It is important to stress that the argument for colour categories being a function of language does not lead to an open house. There are constraints on colour categorisation 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 colour space but excludes an area between them. The constraint can explain, for example, why there is no language category that includes yellow and blue but excludes green. There is simply no associative chain of perceptual similarity that could connect yellow to blue without passing through green.

Another constraint concerns the type of categorisation task. We are concerned here predominately with perceptual categories. Even perceptual categorisation tasks can sometimes be solved simply by perceptual similarity or common association. Monkeys, for example, can categorise different exemplars of a 3 as the same as each other but different from exemplars of a B (Ref. 35). However, the categorisation task is simpler than sorting colours because all within-category exemplars are more visually similar than any cross-category comparison. Other complex tasks can be solved by associations common to exemplars. L.E.W., for example, could use his intact knowledge to categorise animal pictures as native or foreign on the basis of those that are found in zoos[15].

Conclusions

The evidence prompts the conclusion that perceptual categorisation is determined by linguistic relativity. The word 'determined' is used deliberately, even if provocative. It is only by the application of colour labels that categorisation can begin, and thus the conceptual colour-naming train get going. To make this conclusion clearer, a distinction needs to be made between being able to attend to colour and understanding colour categories. Comprehending no colour names does not prevent children from making use of colour attributes, rather than, say, shape attributes, in problem solving[36]. However, even if hearing colour names helps in directing attention to the colour attribute of objects, the task of truly comprehending colour names is different, and indeed difficult. Soja[36] informs us that normal two-year-old children, who know no colour words, take, on average, as many as 800 trials to learn the apparently simple task of responding 'red' to red objects and 'green' to green objects – solving the Sorites paradox is not easy for the child. Indeed, we could even speculate that human language might have evolved to solve the otherwise intractable problem of producing categories that cannot be established by judgments of perceptual similarity.

A more moderate view would agree that experience determines colour categories, but would question whether verbal labels *per se* are necessary. For example, important coloured exemplars[37,38] in the child's world could promote, by the differential

Questions for future research

- Can non-human primates form perceptual categories?
- There is evidence that neonates show colour categorisation. Does this reflect categorisation of a different type?
- Are there capacity constraints on perceptual categorization?
- Verbal interference affects categorisation in memory tasks. Is the same true for perceptual tasks?
- Which brain areas are involved in perceptual categorisation?

weighting through experience, the colour boundaries within different cultures. The terms 'nol' and 'wor' in Berinmo, for example, also refer to whether leaves are edible or non-edible[27]. But it is critical to remember that the Berinmo use their colour names as abstract terms[27]. They have the defining property of superior cross-category discrimination[28]. It is by no means clear how experience with exemplars would be enough to allow this to be accomplished (see Fodor[39] for the limitations of learning by association).

The importance of language for perceptual categorisation seems less surprising, given the evidence of linguistic relativity in other areas of cognition. There is cross-lingual evidence to support the Whorfian hypothesis in the number domain[40], in space[41,42], time[43] and even speech perception[44]. There is also much evidence that language and cognition interact: children readily extend new words and assume words have a common referent. Indeed, the role of language in stimulating categorisation is not limited to the case of object concepts or simple perceptual categories[45,46]. Gentner[45] showed that children would only generalize an abstract term such as 'symmetry' if they learned a label to denote the concrete-learning situation. On-going work will more closely examine the development of perceptual categories within the individual child.

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