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Short report

Categorisation of three-dimensional stimuli by humans and baboons: search for prototype effects

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Abstract

A symbolic matching-to-sample procedure was adopted to investigate whether humans ($n = 2$) and baboons ($n = 2$) discriminate more accurately the prototypes of polymorphous categories than less typical exemplars. Subjects were initially trained to discriminate between two categories of stimuli defined by the possession of any two out of three possible binary features. In transfer, prototypes, which contained all the three feature values of their categories, and novel two-out-of-three feature exemplars were presented for discrimination. Humans solved the task in a propositional way, and showed no evidence for a better performance with the prototypes than with other exemplars. By contrast, monkeys classified the prototypes more accurately than the other exemplars. The analysis of training performance showed however, that their discriminations did not involve prototypical representations of the categories, but rather depended upon feature–and exemplar–response associations. It is argued that monkeys' better performance with the prototypes rested on peak shift and/or novelty effects. © 1997 Elsevier Science B.V.

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1. Introduction

There is a large literature, mostly on birds (e.g. Cerella, 1979; Herrnstein and Loveland, 1964), and less often on nonhuman primates (e.g. Schrier et al., 1984), showing animals' abilities to classify

pictures of objects from a variety of categories, such as pictures of trees or bodies of water (Herrnstein et al., 1976), or pictures of people (D'Amato and Van Sant, 1988). Although this capacity suggests the use of categories or concepts (Herrnstein and Loveland, 1964), the nature and extend of categorical representations in animals remain unclear. In particular, it is still unknown whether

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animals accurately determine the membership of the stimuli by referring to prototypes, or whether they memorise series of exemplars (Thompson, 1995).

One possible way to investigate the issue of categorical representations is to search for a prototype effect. This effect, which was initially reported in the human literature (e.g. Posner and Keele, 1968; Rosch and Mervis, 1975), is expressed by a better categorical performance with prototypical stimuli representing the central tendency of the categories than with other, less typical, exemplars. Assessments of the prototype effects in humans often imply the use of polymorphous stimuli, i.e. stimuli for which no single feature is either necessary or sufficient to determine category membership (e.g. Dennis et al., 1973). For instance, Rosch et al. (1976) used human-shaped stick figures for which the diameter of the head and the length of the torso, arms and legs were manipulated in an orthogonal way.

In pigeons, Von Fersen and Lea (1990) searched for a prototype effect by using pictures of two buildings. The pictures differed along five two-valued dimensions, such as camera distance and camera orientation. When presented with the prototypical pictures containing all the five positive feature values, pigeons showed a higher rate of responding than with any other picture. A similar prototype effect was also reported by Aydin and Pearce (1994). In this study, pigeons were trained to discriminate between compound stimuli comprising features that were more frequently reinforced than others. Then, both the prototypes and positive training stimuli were displayed in an extinction procedure. Pigeons showed the highest rate of responding when the stimuli comprised all the most reinforced features, and complementary, the lowest rate of responding when the stimuli comprised the less reinforced features. This result indicates that the prototypes were more strongly associated to the response than the non-prototype forms. Note, however, that in these last two studies, prototypical forms were presented to subjects before testing.

The above findings contrast with other reports suggesting that the prototypes and non-prototype stimuli are equally discriminable in animals (e.g.

Huber and Lenz, 1993; Jitsumori, 1993; Lea and Harrison, 1978; Lea et al., 1993). For instance, Watanabe (1988) reported that pigeons trained to discriminate distorted triangles made of dots responded more often to novel distorted triangles than to canonical, undistorted, ones. In the same vein, Pearce (1989) trained pigeons to discriminate between two categories of artificial stimuli, defined by the average size (either short or tall) of three adjacent bars. In transfer, subjects showed better discrimination between stimuli of extreme sizes, than between the prototypes representing the average bar-size of each category.

To our knowledge, one study only (Jitsumori, 1994) has assessed prototype effects in nonhuman primates. In this research, artificial stimuli defined by three two-valued positive or negative dimensions (colour, shape and background colour) were presented to rhesus monkeys (*Macaca mulatta*). The stimuli used in training included only two of the three positive or negative dimension values. In transfer, both the prototypes and novel exemplars of the two categories were shown to the animals. Three of the five monkeys demonstrated a high level of transfer with the prototypes containing all the three positive or negative features. However, for those monkeys, there was no statistical difference between the performance achieved with prototypes and that obtained with the non-prototypical stimuli.

Given the contrasted evidence for the use of prototypical representations in animals, the present experiment further investigated prototype effects by testing two different species of primates. Thus, identical polymorphous artificial stimuli were presented, to both humans and baboons, in a symbolic matching-to-sample task. In line with Jitsumori (1994), the rationale of this experiment was, first, to train subjects to classify two-out-of-three feature stimuli and, second, to assess transfer of performance with the prototypes of each category which were never presented before. Data analyses searched for possible prototype effects in both species, and moreover, focused on species differences and resemblances in categorical procedures.

2. Method

2.1. Subjects

A 27-year-old woman (H01), a 23-year-old man (H02), and two 7 year old male baboons (*Papio papio*: B03 and B07) served as subjects. Humans self-reported that they had normal or corrected to normal, visual acuity. They volunteered to participate for pay and were not informed of the purpose of the experiment. The baboons were already familiar with the matching-to-sample procedure (Fagot and Deruelle, 1997; Fagot et al., 1997; Hopkins et al., 1993; Vauclair et al., 1993), but were naive with respect to the two-out-of-three categorisation task. They were not food deprived, but received their food ration (monkey chow, fruits and vegetable) at the end of daily testing.

2.2. Apparatus

The set-up comprised a 14 in. colour monitor driven by a PC 486-AT computer, and an analogue joystick controlling the displacements of a cursor on the screen. Baboons were tested inside an experimental cage (68 × 50 × 72 cm) facing the monitor and the joystick. This cage comprised a view-port, two hand-ports for joystick manipulation, and a dispenser for food pellets. The set-up for humans was the same as for monkeys, except that the monitor was laid at eye-level on a table, and a chin-bar, instead of a view-port, was used to keep constant the viewing distance (i.e. 48 cm).

2.3. Stimuli

As shown in Fig. 1, stimuli were rectangles containing two local elements. The three relevant binary features of the stimuli were their colour (blue or yellow), the shape of the local elements (polygon or semicircle), and their location within the rectangle (upper or lower part). There were two categories of stimuli, which will be referred to as 'C1' and 'C2' (Fig. 1). C1 stimuli comprised at least two of the following feature-values: a blue colour, polygons, and local elements in the upper part. By contrast, C2 stimuli had at least two of the alternative feature-values (i.e. a yellow colour,

semicircles, and local elements in the lower part). For each category, there were three different stimulus types containing two of the three relevant features, and one prototype containing all the three relevant feature-values (Fig. 1). For reasons of clarity, stimuli will be named by sets of three letters, each indicating a specific feature-value: C for background colour, S for shape and L for location. Upper case letters refer to the feature-values of C1 (C = blue, S = polygons and L = upper part). Lower case letters refer to the specific feature-values of C2 (c = yellow, s = semicircles, l = lower part). Therefore, prototypical stimuli will now be referred to as 'CSL' for C1, and 'csl' for C2.

Altogether, the stimulus set comprised 14 exemplars of each prototype, and 15 exemplars of each non-prototypical stimulus type, resulting in a total of 118 different stimuli. Exemplars were made by varying the location of the local elements in the designated upper or lower part of the rectangle. Whatever the stimulus, the local elements comprised 200 grey pixels isoluminant with the background. Note that, with these stimuli, performance was unlikely to be determined by non-relevant salient cues (Lea and Ryan, 1983; Ryan and Lea, 1990), such as the overall luminosity of the shapes or other uncontrolled stimulus attributes (e.g. background colour: Green, 1983).

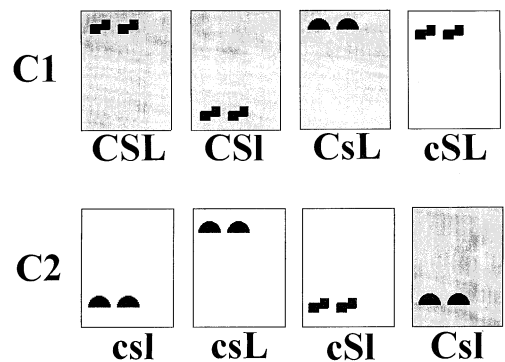


Fig. 1. Illustration of the stimuli. For both 'C1' (upper line) and 'C2' (bottom line), the first column shows a representative example of the prototypical stimuli (either 'CSL' or 'csl'), and the other three columns show examples of non-prototypical two-out-of-three stimuli. The blue and yellow colours of the actual stimuli are represented by grey and white backgrounds, respectively.

2.4. Testing procedure

The task involved a training phase followed by a transfer phase. The training phase, which was designed to have subjects learning C1 and C2, involved all the non-prototypical stimuli (Fig. 1). The transfer phase assessed prototype effects, by presenting the two prototypes (CSL and csl) as well as novel exemplars of non-prototypical stimuli (e.g. Csl).

Trials of both phases involved a symbolic matching-to-sample procedure. A trial began by the display of a green cursor (0.5 cm in diameter) in the centre of the monitor, along with a white 0.5×0.5 cm 'start' stimulus, 1.5 cm above or below the cursor. By manipulating the joystick, subjects were required to place the cursor on the start stimulus in order to initiate sample stimulus presentation. Once this had been done, a sample stimulus belonging to either C1 or C2 appeared for 800 ms in the left or right hemi-part of the monitor. Then, both a pink and a green 3×3 cm square-shaped response stimuli appeared on the vertical axis of the screen. Subjects were required to manipulate the joystick so as to 'touch', with the cursor, the pink response stimulus when the sample was from C1 or, otherwise, to touch the green response stimulus. For baboons, correct responses gave rise to the delivery of food pellets. Incorrect responses were followed by a time-out ranging from 2–5 s. For humans, the outcome of the trial was indicated by either the French word 'faux' (i.e. wrong) or 'vrai' (i.e. right) appearing during 250 ms in the centre of the monitor.

The training phase involved five different exemplars of each of the six non-prototypical stimuli, for a total of 30 different stimuli. During training, sessions of 120 trials were repeatedly presented, until subjects met a criterion of 80% correct over the session. Within a session, each training stimulus was used four times as the sample form. The order of sample presentation was randomly selected prior to each session, in order to have subjects learning the two categories rather than remembering a fixed series of events.

The transfer phase consisted of four sessions of 88 trials each (i.e. 352 test trials per subject). Each test session involved 14 trials in which the sample

Table 1
Subjects' testing performance as a function of stimulus type

Stimulus	B03 (%)	B07 (%)	H01 (%)	H02 (%)
Category 'C1'				
CSL	98	96	0	0
CSl	90	75	100	95
CsL	80	90	98	100
cSL	70	82	100	95
Category 'C2'				
csl	91	91	0	0
csL	92	58	98	100
cSl	65	92	100	93
Csl	20	15	100	100
Mean	78	77	69	68

was the prototype of C1 (CSL), 14 trials in which the sample was the prototype of C2 (csl), and 60 trials in which the sample stimulus was equally often selected from each non-prototypical stimulus type. Test stimuli were all different from those used in training. The order of sample stimulus presentation was pseudo-randomly determined with the constraint that no more than three consecutive trials involved the same categorical response. After testing, humans were asked to verbally report the strategy they used for categorisation.

3. Results

Baboons needed a large number of training trials to reach the learning criterion (B03: 20 400 trials; B07: 14 200 trials). In the transfer phase, B03 and B07 performed at 77.6 and 76.6% correct on average, respectively. Individual performance in the transfer phase as a function of stimulus type is reported in Table 1. This table indicates that performance varied as a function of stimulus type. To demonstrate this effect, arcsine transformations were applied on score data. Then, an analysis of variance (ANOVA) was computed, in which the stimulus type was used as the single independent variable. This analysis demonstrated the main effect of stimulus type as significant, $F(1,7) = 5.82$, $P < 0.02$. Although CSL and csl gave rise to the highest two scores, the significant

effect of stimulus type was mainly due to Csl (Tukey honestly significance method, $P < 0.05$; Fig. 2), for which average performance was at 24% correct.

In a complementary analysis, we more directly compared performance achieved with prototype and non-prototype stimuli. Hence, an ANOVA was computed on transformed score data in which the type of sample (i.e. prototype or non-prototype stimuli) served as the single independent variable. Average performance achieved with the prototypes (mean = 76.3% correct) was significantly greater than that obtained with non-prototype stimuli (mean = 57.36% correct; $F(1,1) = 1368.8$, $P < 0.02$). This effect remained significant even when the Csl stimuli were excluded from the analysis, $F(1,1) = 228.7$, $P < 0.05$.

The learning process was much faster for humans than for baboons, and only three training

sessions (i.e. 360 trials) were needed to reach training criterion. Considering the transfer phase, average performance was 68.5% correct for H01, and 67.6% correct for H02 (Table 1). Arcsine transformed score data were subjected to an ANOVA with the stimulus type factor serving as the single independent variable. The main effect of stimulus type was statistically significant, $F(1,7) = 43.84$, $P < 0.001$. Post-hoc analyses (Tukey HSD, $P < 0.05$) showed lower performance with the prototypes (CSL: mean = 9.3% correct; csl: mean = 5.7%) than with other forms (range 82–90% correct; Fig. 2). There was no significant difference (Tukey HSD, all $P < 0.1$) between the non-prototype stimuli. In sum, the data set provided no evidence for a prototype effect in humans, because prototypical stimuli were erroneously classified.

4. Discussion

The aim of this comparative study was to investigate prototype effects in a task implying the categorisation of polymorphous stimuli. In agreement with previous findings on macaques (Jitsumori, 1994) and pigeons (e.g. Lea and Harrison, 1978), results demonstrated that baboons are able to solve two-out-of-three categorisation problems and furthermore, to generalise to novel stimuli. Data indicated, moreover, that monkeys, but not humans, achieved better categorical performance with the prototype than with the non-prototype stimuli. In the following discussion, we will argue that differences in performance level between prototypes and non-prototype stimuli rested on a peak shift effect (Hanson, 1959), rather than on a prototype effect (Medin and Schaffer, 1978; Rosch, 1978). We will also argue that species differences in categorical procedures are rooted in differential abilities to solve the task, that is in a propositional way for humans, and predominantly in an associative way for baboons.

4.1. Did baboons use prototypes?

Although, during the transfer test, baboons performed better with the prototypes than with

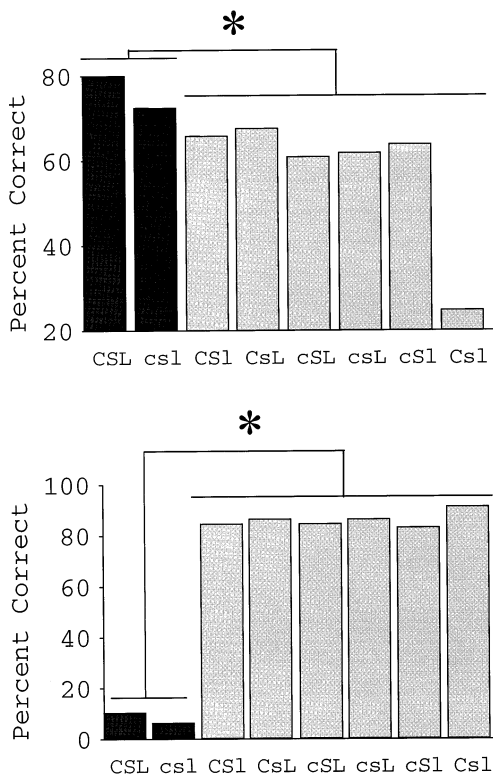


Fig. 2. Arcsine transformed mean percentages of correct responses in the transfer test, for both baboons (top) and humans (bottom), depending on stimulus type. * = $P < 0.05$.

Table 2
Baboons' training performance as a function of stimulus type

Stimulus	B03		B07	
	NTT	LAST (%)	NTT	LAST (%)
Category 'C1'				
CSl	4000	82	6000	84
CsL	4000	73	4000	76
cSL	16 000	71	10 000	77
Category 'C2'				
csL	8000	77	6000	75
cSl	6000	73	6000	100
Csl	—	60	—	50

NTT, Number of trials needed to reach and maintain a performance of 60% correct or more over classes of 2000 consecutive training trials; LAST, percentage correct in the last 100 presentations of each stimulus type in the training phase.

the non-prototype stimuli, several aspects of our data suggest that these animals did not use prototypical representations of the two categories. The main arguments against a prototype effect can be derived from the data reported in Table 2.

For each baboon and stimulus type, Table 2 provides the number of training trials that were necessary to reach and maintain performance above 60% correct. Notice that, for both subjects, a very large number of training trials was needed to achieve criterion. The length of the training can be explained by the procedure we have adopted which, in order to enhance category learning, involved presentation of several different exemplars per stimulus type. Despite this procedure, it appears from Table 2 that the two monkeys learned the stimuli in a sequential manner, and moreover, in the same order. Thus, both subjects initially learned the category membership of CSl and CsL for C1, and csL and cSl for C2. As these latter C1 and C2 forms differed by their colour (they were blue for C1 and yellow for C2), results suggest that the background colour was used as a predominant cue for discrimination, at least early in training. Table 2 also indicates that cSL and Csl, which differed in colour from all the other stimuli of their category, were the most difficult stimuli to learn. Indeed, cSL required as many as 10 000 trials or more to be learned, and Csl was

never correctly classified as belonging to C2, even after 14 000 (B07) and 20 000 (B03) training trials. In sum, the sequential aspect of the learning process suggests that the baboons initially learned strict colour/response associations, and then learned the category membership of the exemplar cSL, rather than prototypes.

It might be proposed that, although not referred to during learning, the prototypes were used as needed during the test phase (Komatsu, 1992). However, as shown in Fig. 2, during the transfer test the two baboons systematically classified Csl as belonging to C1 (in 80 and 85% of the trials for B03 and B07, respectively). Therefore, from the standpoint of baboons' knowledge, C1 included CSl, CsL, cSL and Csl, and C2 only comprised csL and cSl. This unexpected category membership rules out the possibility to treat CSL and csl as the prototypes, because they no longer represented the central tendency of their category. In sum, the baboons generalised learned associations acquired during training to all the novel stimuli except Csl, and they behaved as if, during the transfer phase, they classified CSL, csl and Csl on the basis of their background colour only.

Why, then, did the two prototypical forms give rise to the highest performance, if they were not processed as prototypes? According to McLaren et al. (1995), better performance with prototypes in this type of task may reflect either a peak shift and/or a prototype effect. The 'peak shift effect' was initially reported by Hanson (1959). This author rewarded pigeons to peck 550 nm lights (S+), and to refrain from pecking when 560 nm lights (S-) were presented. On post-discrimination trials, pigeons pecked more rapidly at novel 530 nm and 540 nm lights than at the original 550 nm stimulus (S+), although this latter stimulus was used in training. This peak shift effect might be explained by a greater distance, in term of similarity, between the novel stimuli and S-, than between S+ and S-, which would have enhanced the associative strength between the novel stimuli and the reward. It is proposed that a similar effect may have occurred in the context of our experiment. Under this hypothesis, CSL was more strongly associated to C1 than the three non prototypical forms of C1, because of its greater

distance to C2 (e.g. in the number of common feature values). The same peak shift effect could have occurred with csl, which shared more features with the non prototypical forms of C2 than with those of C1.

Another explanation of the performance achieved with CSL and csl refers to a novelty effect. It should be reminded that all the stimuli used in transfer were novel. However, the relative novelty of CSL and csl was greater than that of all the other stimuli. Thus, novel non prototypical stimuli differed from the training stimuli only by the location of their elements, whereas CSL and csl were different from the training stimuli by both the position of the elements and the presence of the three feature-values defining each category. It can be proposed that the novelty factor enhanced the attention level of the baboons, and thus allowed for a better detection of stimulus attributes.

4.2. How did humans solve the task?

In the transfer test, humans showed no evidence for a prototype effect, because they tended to respond C2 to CSL, and C1 to csl. After testing, H01 explained that she firstly learned to associate CSI to C1 (Table 3), and then determined the

Table 3
Humans' training performance as a function of stimulus type

Stimulus	H01		H02	
	NTT	LAST (%)	NTT	LAST (%)
Category C1				
CSI	150	80	300	76
CsL	300	72	100	92
cSL	250	84	300	68
Category C2				
csL	150	88	200	80
cSl	300	72	150	84
Csl	300	80	250	76

NTT, Number of trials needed to reach and maintain a performance of 60% correct or more over classes of 50 consecutive training trials; LAST, percentage correct in the last 25 presentations of each stimulus type in the training phase. Class sizes were smaller than in Table 2, because humans were much faster than baboons to learn the task.

category membership of the other stimuli by counting the number of features which departed from this form of reference. The rule was to select C2 when either one or three features differed from CSI, and to select C1 when the stimulus differed from CSI by two features. H02 applied a similar computational strategy, except that he firstly learned CsL (Table 3). It can thus be concluded that the two subjects solved the task in a propositional way, instead of by referring to prototypical representations. Jitsumori (1993) reported similar strategies in humans.

In summary, neither humans nor baboons exhibited evidence for the use of prototypes in our experiment. Whether our subjects would show a prototype effect in different experimental contexts remains an empirical question. In particular, it is possible that the use of binary-valued features have encouraged application of logical rules by humans, and exclusive feature-exemplar learning by baboons. If this reasoning is correct, then the use of multiple-valued features is expected to favour acquisition of prototypes. Further experiments will tell whether monkeys or humans would rely on prototypical representations in such experimental conditions.

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