CPC, 1996, 15 (5), 449-462

Categorization of alphanumeric characters by Guinea baboons: within- and between-class stimulus discrimination

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Abstract

Using a videotask requiring the manipulation of a joystick, we explored how baboons categorize alphanumeric characters displayed in various typefaces. Two baboons were trained in a symbolic matching-to-sample task with 21 different fonts of the characters *B* and *3* as sample forms, and colored squares as comparison forms. After training, there was a positive transfer of performance to novel fonts (Experiment 1). This transfer relied on the use of categorical procedures, because an identity matching-to-sample task showed accurate discrimination between exemplars belonging to the same category (Experiment 2).

Key words: Categorization, matching-to-sample, videotask, baboons.

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INTRODUCTION

During the last two decades, a large number of studies have been conducted on the ability of animals (mostly pigeons) to form categories and "concepts" based on natural categories (e.g., Herrnstein, 1979; Cerella, 1979; Lea & Ryan, 1983; Bhatt, Wasserman, Reynolds, & Knauss, 1988; Roberts & Mazmanian, 1988; Rilling, De Marse, & La Claire, 1993). These studies have provided evidence of the use of categorical processes in these animals (e.g., Herrnstein, 1990). So far, there has only been a limited number of studies on the ability of monkeys or apes to form categories or "concepts" (Schrier, Angarella, & Povar, 1984; Gardner & Gardner, 1984; Yoshikubo, 1985; D'Amato & van Sant, 1988; Roberts & Mazmanian, 1988; Jitsumori, Wright, & Shyan, 1989; Jitsumori, 1993, 1994; Neiworth & Wright, 1994). Moreover, the available studies have provided contrasting evidence for conceptualization. For example, Jitsumori (1994) trained rhesus monkeys to discriminate between categories of polymorphous artificial stimuli defined by the possession of 2 out of 3 positive or negative features (the features were the color and shape of form items, and the color of the background). Three out of five monkeys were able to generalize to novel stimuli containing all three positive or negative features (Experiment 1), but their performance was disrupted if one of the three features was replaced by a novel one (Experiment 2). This evidence suggests that classification rules may apply only to the stimulus set used in training.

Wasserman, Kiedinger, and Bhatt (1988) and Thompson (1995) claimed that proper demonstration of categorization requires the use of a two-step procedure. It must be demonstrated in the first step that the subject can discriminate objects belonging to different categories. The second step involves demonstrating that stimuli to be classified in the same category are discriminably different from one another. But very few studies have followed this two-step procedure (Thompson, 1995). The inability of pigeons to perform within-class discriminations was demonstrated by Cerella (1979), although pigeons proved capable of performing between-class discrimination (i.e., oak leaves versus non-oak leaves). This failure suggests some limited categorical abilities in this species. In nonhuman primates, Sands, Lincoln, and Wright (1982) showed that rhesus monkeys tested with a same/different task and presented with pictures of different categories (e.g., face, fruit) made more confusion errors when the two choices belonged to the same category (e.g., fruit) than when they were from different categories.

The goal of the present study was to investigate the issue of within- and between-class discrimination in monkeys. We used alphanumeric characters as stimuli in order to experimentally control for subjects' previous experience with stimuli (Morgan, Fitch, Holman, & Lea, 1976). Using the characters *A* and *2* displayed in different typefaces, Schrier et al. (1984) demonstrated the ability of stumptailed macaques (*Macaca arctoides*) to discriminate between these two classes of stimuli, and to transfer their performance to novel fonts of the same characters. However, a critical control was lacking because the authors did not verify whether or not their subjects could discriminate between exemplars belonging to the same category.

This paper reports two experiments. The first one assessed the problem of between-class discrimination, and was thus a replication with baboons of Schrier et al.'s (1984: Experiment 4) study. A symbolic matching-to-sample task (Herman & Thompson, 1982) was used and required joystick manipulation as the response. One of the advantages of this novel methodology in comparison to the previous work by Schrier et al. (1984) was that in addition to the accuracy scores of the subjects, their response times could be recorded, thus providing an additional dependent variable for statistical analyses. The second experiment specifically examined the issue of within-class discrimination with the same set of stimuli as in Experiment 1. This objective was achieved with an identity matching-to-sample task.

EXPERIMENT 1

Method

Subjects. The subjects were two wild-born subadult male baboons (*Papio papio*) – referred to as 03 and 07 – each weighing about 13 kg during the test. The baboons were housed as a social group of eight animals reared in indoor and outdoor quarters at the primate facilities of the "Centre de Recherche en Neurosciences Cognitives", Marseille, France. They received their daily food ration (fruit, monkey chow and vegetables) at the end of daily training and testing.

Apparatus. The equipment included a PC-AT microcomputer and the experimental cage (50 × 70 × 68 cm) depicted in Figure 1. The front of the cage was equipped with a view port (8.7 × 8.0 cm), two hand ports, an analogue joystick adjacent to a touch pad, and a 14-in color monitor.

The cage was equipped with a food dispenser which provided 190-mg food pellets when correct responses were made. The experiment was driven by a software program written in Turbo Pascal 5.0. Timing of stimulus presentation and recording of response times were controlled at a 1-ms sampling rate.

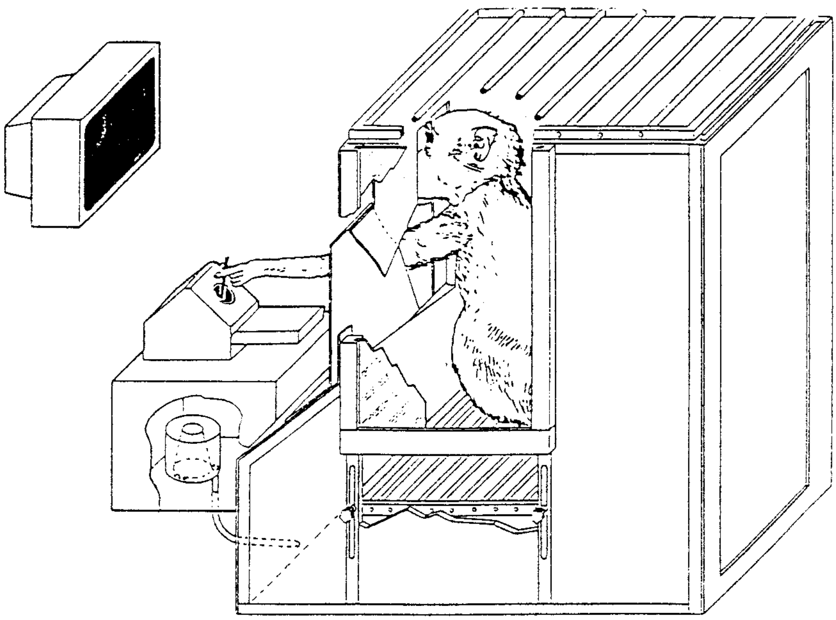

Figure 1. Test apparatus.

Procedure. During all training and testing, each subject was removed from its social group and was individually placed in the experimental cage. The testing conditions were based on the symbolic matching-to-sample procedure. After presentation of the sample stimulus, two colored square stimuli were displayed on the screen. The subject then had to select, between two comparison squares, the one that was associated with the sample on an arbitrary (experimenter-defined) basis.

At the beginning of each trial, the baboon had to place its hand on the touch pad. This action led to the immediate display of a cursor (a 0.5 cm-diameter green circle) in the center of the screen, and a small white square (0.5 × 0.5 cm), 1.5 cm above or below the cursor.[1] The subject then had to manipulate the joystick so as to place the cursor on the white square. Once the cursor was on the white square, a sample stimulus (3.5 × 3.5 cm) was displayed on either the left or right side of the screen. In each trial, the sample stimulus was an alphanumeric character (e.g., a *3*) selected from a set of two characters (e.g., *3* or *B*) that could be depicted in different fonts. These stimuli were made using the software Keyfonts for Windows 3.1 (Softkey Software Product Inc., Boca Raton, FL).

Immediately after the display of the sample stimulus, two comparison square stimuli of different colors appeared 4 cm above or below the cursor on the vertical axis of the computer screen. The subject had to manipulate the joystick to make the cursor "touch" the square that corresponded to the category of the sample. A correct response was recorded when the subject selected the stimulus that corresponded to the sample category. Correct responses were always reinforced with a food pellet and were accompanied by a tone. Incorrect responses were never reinforced, but were followed by a low raucous tone and a time-out of 3 seconds. This reinforcement contingency was in effect during the pre-training, original training, and transfer phases.

Pre-training. Both subjects had already learned to manipulate a joystick to control the movements of a cursor displayed on a computer monitor (Vauclair & Fagot, 1993). Subjects had also been extensively trained to solve pattern discrimination problems (see Fagot & Vauclair, 1994; Hopkins, Fagot, & Vauclair, 1993; Vauclair, Fagot, & Hopkins, 1993; Wilde, Vauclair, & Fagot, 1994), but were naive with respect to the symbolic matching-to-sample procedure.

Training. Training on the matching-to-sample task was done in three phases. Mastery of any phase required an accuracy level greater than

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1. This study is part of an ongoing project devoted to the question of functional asymmetries in baboons (e.g., Vauclair & Fagot, 1993; Fagot & Vauclair, 1994). During the testing phase, the sample form was presented in one visual half-field at a time in order to restrict the visual input to the opposite hemisphere. This procedure required the use of a fixation point (i.e., the white square) that the subject had to "foveate" before sample presentation. Although available, the laterality data will not be presented in this paper, mostly because the number of subjects precludes drawing conclusions at the population level.

80% across 100 trials. Phase 1 was designed to have the baboons acquire the basic principles of the symbolic matching-to-sample task. In this phase, only two stimuli, a capital *A* and a capital *N* (selected for their apparent discriminability), were used alternatively as the sample. In phase 2 of the training, the task was kept similar except that the sample stimulus was selected among a set of 8 *A's* and 8 *N's* of different typefaces. In phase 3, the sample presentation time was gradually reduced from 800 ms to 120 ms until the animal reached the criterion at 120 ms. Whatever the training phase, subjects received an average of 100/300 trials per day. Overall, training required 5,283 trials for baboon 03 and 11,370 trials for 07.

Testing. Testing was done in two experimental phases (original training and transfer). For both phases, the stimuli were different from those used in the symbolic matching-to-sample pre-training. During the original training, 42 yellow 3.5 × 3.5 cm alphanumeric characters (21 *B's* and 21 *3's* in different typefaces) were used as samples. They were randomly selected from the fonts available in the KeyFonts software. The entire set of stimuli used in the original training is depicted in Figure 2.

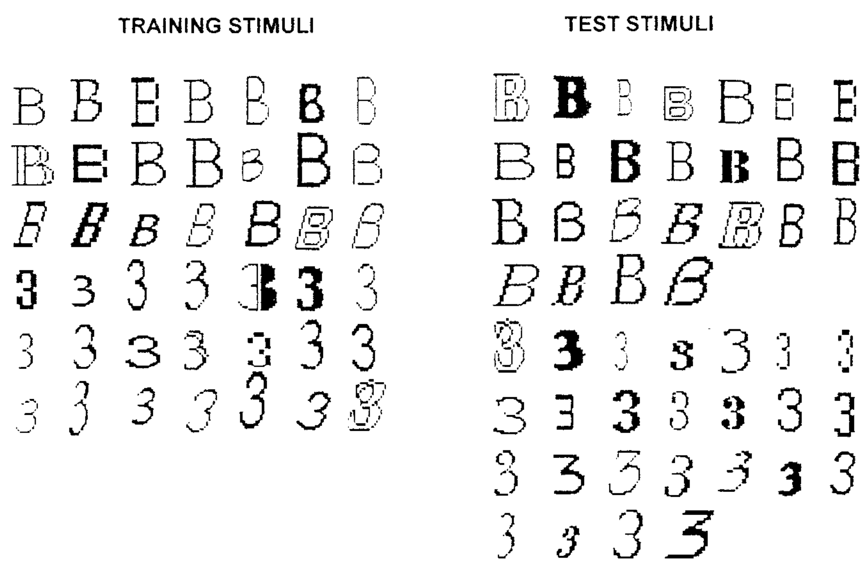

Figure 2. Left: the 42 stimuli (21 3's and 21 B's) used in the original training. Right: the 50 stimuli (25 B's and 25 3's) used in the transfer phase.

The original training consisted of one to three blocks of 168 trials a day, until the criterion of 80% correct trials over 100 consecutive trials was met. Within a block, each stimulus was used four times as the sample stimulus. The two comparison stimuli were a yellow and a light blue 3.5 × 3.5 cm square. Regardless of the font, the baboon had to select the yellow stimulus if the sample was a *B*, and the blue stimulus if the sample was a *3*. The location of the comparison stimuli, either at the top or at the bottom of the screen, was counterbalanced across trials with the constraint that no more than 3 "up" or "down" responses were requested in a row. At the beginning of the original training, the sample stimulus was displayed for 800 ms, and a correction procedure was adopted. With this procedure, after an incorrect response, the trial was presented again within the next three trials. Once subjects met the criterion under these conditions, the presentation time was decreased (from 800 to 120 ms), and the correction procedure was abandoned. Then, the subject was retrained until it reached the criterion again. Then the transfer phase began.

The transfer test consisted of 168 trials per subject. In this phase, the sample stimuli were selected among the 34 familiar stimuli used in the original training (17 *B's* and 17 *3's*), or among 50 novel stimuli. The novel stimuli (25 capital *B's*, and 25 *3's*) were all shown in typefaces that differed from the ones used in the original training. The set of stimuli used for transfer is shown in Figure 2. Each stimulus was used twice during transfer, and correct choices on test trials were food-rewarded.

Results

In the original training, subject 07 needed 1,144 trials to learn the discrimination at criterion level (i.e., 80 correct trials over 100 consecutive trials). Subject 03 learned in 1,580 trials. The number of trials needed for the original training was thus substantially lower than for pre-training, which may be accounted for by the greater familiarity with the symbolic matching-to-sample task. Because the number of training trials varied from one original training session to the next, repeated trials due to the application of the correction procedure were omitted, and the remaining trials were arbitrary grouped into series of 200 trials to assess learning effects. Subject 03 performed at 50%, 53.5%, 59%, 73%, 83.5% on blocks 1-5, respectively. Subject 07 performed at 51.5%, 67%, 78%, 82%, 81% on the same five blocks. Note that performance was above chance for the first time on the third block of 200 trials ($\chi^2(1, N = 200) = 6.5, p < .05$) for subject 03 and on the second block of 200 trials (67 percent correct, χ^2, $p < .01$) for subject 07.

The results of the transfer test with novel stimuli are given in Table 1, along with performance data on the 68 trials with familiar stimuli. Both subjects performed significantly above the chance level ($p < .05$) when novel stimuli were presented. Because in the transfer test each stimulus was presented twice, the percentage of correct responses was calculated for the first presentation only. In that case, 03 succeeded in 80% of the trials ($\chi^2(1, N = 50) = 18, p < .001$), and 07 succeeded in 68% ($\chi^2(1, N = 50) = 6.48, p < .02$), demonstrating a transfer effect upon the first presentation of the novel stimuli.

In an additional analysis, we compared response times for correct trials with familiar and novel stimuli. Because subjects could be very slow in responding due to distraction, trials were discarded when the response times were more than 3 *SD*s above individual means. Only four trials were dropped as a result of this reduction procedure. Two-tailed *t*-test analyses showed that, for both 03 and 07, correct response times did not differ between familiar and novel stimuli (03: $t(132) = .46$, n.s.; 07: $t(123) = .52$, n.s., see Table 1). This was also true when only response times for the first presentation of the novel stimuli were considered (all $ps > .1$).

Table 1
Experiment 1: Correct response rate and mean response times (in milliseconds) for familiar and novel stimuli in the test phase of the symbolic matching-to-sample task

	Familiar stimuli		Novel stimuli	
	% correct	RT	% correct	RT
03	85.2	843	78.0	867
07	79.4	1392	73.0	1450
Mean	82.3	1117	75.5	1158

RT = mean response time.

Discussion

The response times and accuracy scores indicated a high level of transfer of categorical performance when the monkeys were tested with novel fonts of the characters used in the original training. This result demonstrates that the original learning was not achieved by rote learning, because in that case, the animals would have demonstrated no transfer to the novel typefaces (Herrnstein, 1990). It might be argued, however, that the stimuli composing each category in either the original training or the transfer phase were not discriminably different. Such indiscriminability could explain the high performance achieved by the two subjects. Experiment 2 will address the issue of the discriminability of exemplars when they belong to the same *3* or *B* category.

EXPERIMENT 2

Method

Whereas categorization was investigated in Experiment 1 with a symbolic matching-to-sample procedure, a different matching rule was used in Experiment 2. After sample presentation, two comparison stimuli appeared on the vertical axis of the screen. One form stimulus was identical to the sample, and the other was the same alphanumeric character as the sample, but displayed in a different font. To be rewarded, the baboons had to select the comparison form that was identical to the sample. Therefore, the task was an identity matching-to-sample task rather than a symbolic matching-to-sample task. Prior to the test, baboons were trained to criterion (80% correct over 100 consecutive trials) on the identity matching-to-sample task with a set of stimuli (random geometric forms) that was different from the two sets used in the testing sessions.

The same two subjects as in Experiment 1 (i.e., 03 and 07) performed 84 identity matching trials each with the 21 *B's* of the original training, and 84 trials each with the 21 *3's* of the original training (see Figure 2). For all trials, the comparison form was randomly selected among the stimuli to which the sample belonged. The trial presentation order as well as all the other procedural details were the same as in Experiment 1.

Results and discussion

The two baboons performed above chance level in the identity matching task. One subject (i.e., 03) performed at 77.9% correct on average. When the two characters were considered independently, this subject performed at 83.3% for the *3's* ($\chi^2(1, N = 84)$, $p < .01$) and at 72.6% for the *B's* ($\chi^2(1, N = 84)$, $p < .01$). Because these two performance levels were significantly above chance (χ^2, $p < .01$), they provide strong evidence for discrimination of exemplars within the two categories. The other baboon (i.e., 07) performed at 61.3% correct on average, which was significantly above chance ($\chi^2(1, N = 168)$, $p < .01$). However, when the data were broken down by category, it performed above chance for the *3's* (65.4% correct, $p < .01$), but at chance level for the letter *B* (57.2% correct, $p > .1$). It can thus be concluded for both subjects that the *3's* were more discriminable than the *B's*, because both baboons showed their worst performance with the letter *B*. Moreover, at least when the character *3* is considered, the results are consistent with the hypothesis that baboons may have relied on categorical procedures to respond correctly in Experiment 1.

The question remains as to why the *B's* and the *3's* were not equally discriminable in the baboon's eyes. It could be argued that the short presentation time (120 ms) differentially affected perception of the *B's* and *3's*. This is unlikely, because the same subjects tested with other alphanumeric characters still demonstrated high performance (> 70 percent correct) with extremely brief (50-95 ms) presentation times (Wilde et al., 1994). A more likely explanation is that the difference between the *B's* and the *3's* is related to the intrinsic features of each character (for similar effects with pictures, see Von Fersen & Lea, 1990), or to random biases in the sampling of the stimuli.

GENERAL DISCUSSION

Findings from Experiments 1 and 2 allowed us to draw the following conclusions. In line with Schrier et al.(1984), they demonstrated (1) that monkey species are capable of categorizing subsets of alphanumeric characters, and (2) that they can transfer their categorical procedure to novel fonts. This is also consistent with the results previously obtained for pigeons (Morgan et al., 1976; Blough, 1985). However, as far as nonhuman primates are concerned, Experiment 1 did not demonstrate that stimuli from the same category were perceptually discriminable for the subjects. This issue was addressed in Experiment 2 by using an identity matching-to-sample task. This experiment proved that baboons can recognize some individual forms from exemplars in the same category. The results of Experiment 2 also suggested that this ability is both subject- and stimulus-dependent.

Of course, the current findings are constrained by the type of stimuli used and the species under study. This experiment points out the need for cautious interpretation of transfer data when the subject's ability to perform within-class discrimination has not been assessed. The lower performance we observed in within- compared to between-class discrimination can be explained in terms of the "clumping hypothesis" reported by Bateson and Chantrey (1972), who showed that in chickens and monkeys, initial training in inter-class discrimination makes subsequent intra-class discrimination more difficult. Indeed, proper assessment of categorization requires not only that subjects understand that different objects have common class attributes, but also that subjects can discriminate between members of a category. We think that the two-step procedure should be used systematically in further studies of categorical functions in nonhuman species.

ACKNOWLEDGEMENTS

Authors thank Monique Chiambretto for developing the software, Bernard Arnaud for his mechanical assistance, and Raymond Fayolle for his aid with the electronics. France Lavergne is acknowledged for her help in testing the baboons. The authors also thank S. E. G. Lea, J. J. Neiworth, R. K. Thompson, and an anonymous reviewer for their helpful comments to improve the manuscript.

RÉSUMÉ

Une tâche de catégorisation perceptive a été proposée à des babouins à l'aide d'un système informatique. En ayant recours à un protocole d'appariement symbolique, les singes devaient discriminer des caractères alphanumériques repésentant des "B" et des "3". Après l'apprentissage, les singes sont capables de reconnaître des "B" et des "3"

présentés avec des polices différentes de celles de l'entraînement (Expérience 1). Le recours à des procédures de catégorisation est vérifée dans une autre étude (Expérience 2) qui montre la capacité des babouins à discriminer des exemplaires appartenant à une même catégorie.

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Received 9 May, 1996
Accepted 2 August, 1996