

Natural Images: A Lingua Franca for Primates?

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Abstract: Primates in the laboratory often perform tasks that involve discrimination of pictures shown on computer screens. It is not clear, however, if they perceive the pictures as symbolic representations of real objects. In this study we tested the ability of two monkeys (*Macaca mulatta*) to categorize pictures on a computer screen. The pictures were photographs of objects from 17 categories, which were grouped as natural and familiar, natural and unfamiliar, or artificial and unfamiliar. The monkeys learnt the categories of the natural and familiar objects faster than those of the artificial and unfamiliar objects. Nevertheless, once they had learnt the categories, they were just as fast and accurate at generalizing to new exemplars of artificial and unfamiliar objects. This finding suggests that the monkeys are able to extract similarities and form categories from a small number of stimuli differing widely across size, color and viewpoint, and for which they have no prior internal representation.

Keywords: Rhesus monkey, categorization, learning.

1. INTRODUCTION

It has been reported that members of remote cultures, who are not familiar with pictorial material, do not recognize pictures of familiar faces and objects effortlessly [1]. In addition, familiarity with pictures, as a means of symbolic representation, can be more important for recognition than familiarity with the depicted objects [2]. On the other hand, pigeons and other animals that get extensive practice in the laboratory are able to perform a variety of visual discriminations with pictures, e.g. [3-6]. In particular, research in primate recognition often employs monkeys performing tasks with pictures shown on computer screens, e.g. [7-10]. However, it is not clear if the monkeys perceive the pictures as symbolic representations of familiar objects. We trained two macaque monkeys (*Macaca mulatta*) on a categorization task with natural images from 17 categories, ranging from familiar and natural to unfamiliar and artificial. We hypothesized that if the monkeys perceive the pictures they see on the monitor as representations of familiar objects, then they should learn categories of familiar, natural stimuli faster than categories of unfamiliar, man-made stimuli. Here we present evidence that familiarity of the monkeys with the depicted objects can facilitate learning of their pictorial representations. We also report that in the generalization phase, they are just as fast and accurate at categorizing new examples of artificial as well as familiar objects. This finding suggests that the monkeys are able to extract similarities and form equivalence classes from a small number of stimuli differing widely across size, color and viewpoint, and for which they have no prior internal representation.

2. MATERIALS AND METHODS

We trained two adult, male rhesus monkeys (*Macaca mulatta*), weighing 11.0 and 13.0 kg., to perform a categorization task with natural images following standard operant conditioning techniques. They had been trained on other discrimination tasks with colored shapes, but had no experience with pictures. The images (n=210) were presented on a computer screen and represented natural, familiar (humans, monkeys, food items), natural but not familiar (e.g. bears, snakes), or man-made, not familiar objects (ships, buses, airplanes) (total of 17 categories) (Fig. 1). All studies were in compliance with the guidelines of the European Community (EUVD 86/609/EEC) for the care and use of laboratory animals.

Each color image was shown at 256x256 pixels resolution, subtended 5°x5° visual angle, and were presented on a 21" monitor. The timing of stimulus presentation, the responses and juice reward were computer controlled.

The animals were seated in a primate chair with two response levers mounted at the front. During the learning phase they were familiarized with a subset of images (4 per category) and learned by trial-and-error to respond by pulling one of the levers. The monkeys were familiarized with images sorted by natural category and trained to respond to each one of them by pulling one of two levers. The lever assignment was predetermined by the experimenter. The images represented natural, familiar, natural but not familiar, or artificial, not familiar objects. The left lever categories were: bears, wild cats, monkeys, chimpanzees, parrots, food items, ships and airplanes. The right lever categories were: snakes, salamanders, humans and portraits of human faces, gorillas, orangutans, flowers, leaves and buses. The mean number of exemplars in each category was twelve. We considered as natural and familiar the categories of monkeys, humans and food items. We considered as artificial and not familiar the categories of airplanes, buses, ships and por-

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Fig. (1). **A)** Examples of the images presented in the corresponding categories. **B)** Examples of the within category variability.

traits. The rest of the categories were considered as natural, but not familiar to monkeys that were raised in captivity. During both learning and generalization phase blocks of trials of a particular category were intermixed with blocks of trials from other categories, and never in isolation. The generalization phase started after learning of all categories had been completed. At the beginning of each trial a fixation spot ($1^0 \times 1^0$) appeared in the middle of the screen. After 500ms the fixation spot was switched off and a stimulus was presented until the monkey pulled a lever or for up to 2500ms. The monkeys received auditory feedback for correct responses (high-pitched tone) and were rewarded with a drop of juice. For incorrect responses a delay of 2 seconds was imposed.

We used a criterion of four consecutive correct categorizations for a particular image as a measure of learning, which indicated stable correct performance (chance level

6.25%). If “i” stands for “incorrect” and “c” for “correct”, then for the hypothetical response sequence “ciciccccc”, the learning criterion is achieved after ten trials. During the learning phase, the animals were exposed to four exemplars per category. If the learning criterion is achieved in 9, 28, 9 and 8 trials for each image respectively, then the category is acquired within nine trials (median).

3. RESULTS

Table 1 reports the median number of trials to the learning criterion for the first 4 stimuli that were used to define a category (learning phase). The monkeys learned all categories with a minimum of 4 and a maximum of 23 (median value) trials (see Materials and Methods for learning criterion). To compare the performance of the 2 animals in the different types of categories, we performed a 2 (subject: M1

and M2) x 3 (type of category: natural and familiar, natural and unfamiliar, artificial and unfamiliar) ANOVA on the mean number of trials it took them to acquire the learning criterion. Only the main effect of type of category was significant ($F_{1,3}=5,97$, $p=0.006$), indicating that both animals learned more easily the categories that depicted familiar objects.

Table 1. Order in which the Categories were Introduced to the Monkeys

M1	M2
Flowers (6)	Flowers (5)
Bears (9) L	Bears (5) L
Leaves (6)	Wild Cats (10) L
Parrots (4) L	Leaves (7)
Snakes (9)	Parrots (9) L
Monkeys (4) L	Monkeys (4) L
Humans (6)	Snakes (4)
Salamanders (4)	Salamanders (9)
Chimpanzees (9) L	Chimpanzees (4) L
Portraits (17)	Humans (4)
Ships (23) L	Portraits (8)
Buses (12)	Ships (11) L
Wild Cats (4) L	Buses (10)
Orangutans (4)	Gorillas (5)
Gorillas (6)	Orangutans (7)
Airplanes (12) L	Food items (14) L
Food Items (10) L	Airplanes (9) L

In brackets: number of trials to learning criterion (see Materials and Methods). L: category assigned to the left lever.

After the monkeys had reached the learning criterion for the first 4 stimuli that were used to define a category, they were shown a total of 8 new images to categorize in the classes they had learned. A two-way ANOVA contrasting the mean reaction times (RTs) to the first presentation of the first 4 category exemplars (learning phase) with the RTs to the first presentations of the last 4 category exemplars (generalization phase) showed a significant main effect for the two phases (learning vs. generalization) ($F_{1,2}=6,77$, $p=0.014$) but no effect of category type ($F_{1,3}=0.05$, $p=0.95$). During the generalization phase the new images were presented randomly interleaved and not in blocks of the same category. The mean RT during learning of first 4 exemplars was 987 ± 62 ms (SEM, standard error of the mean), while the mean RT for the last 4 exemplars was 779 ± 50 ms for all category types. A further comparison of the RTs and correct responses to natural and artificial stimuli with a non-parametric test showed no differences across the different categories (two-tailed Mann-Whitney, $\alpha=0.001$). Hence, in the generalization phase and after little training, the monkeys were able to categorize correctly new images, including those of artificial objects.

4. DISCUSSION

The monkeys learned all the categories within the first session they were introduced. There may be several reasons for that. The first might be the fact that, in contrast to previous relevant studies [11], the monkeys did not have to discriminate stimuli on the basis of the presence or absence of the positive stimulus (compare learning rates in experiments 1 and 2 in [11] and also see [12]). Moreover, they were not presented with the same category as positive and then as a negative category [6]. All pictures were assigned to a category and the lever assignment remained the same throughout training and testing. A second reason for the fast learning rates may be the quality of the stimuli. The pictures consisted of relatively close, full figures of the category objects (Fig. 1) and can be characterized as *good* stimuli (as opposed to *poor*) [11] based on the size and the position of the main object in the picture.

There are similarities and differences in the data from the two animals. For both of them, the categories that were learned more easily (4 trials to learning criterion) were categories of animals. For M1, 2 of the 5 and for M2, 3 of the 4 easiest categories were primates: monkeys and orangutans,

Table 2. Median Number of Trials to Learning Criterion

M1		M2	
Category	# Trials	Category	# Trials
Monkeys	4	Chimpanzees	4
Orangutans	4	Monkeys	4
Parrots	4	Humans	4
Salamanders	4	Snakes	4
Wild Cats	4		
		Bears	5
Flowers	6	Flowers	5
Gorillas	6	Gorillas	5
Humans	6		
Leaves	6	Leaves	7
		Orangutans	7
Bears	9		
Chimpanzees	9	Portraits	8
Snakes	9		
		Airplanes	9
Food items	10	Parrots	9
		Salamanders	9
Airplanes	12		
Buses	12	Buses	10
		Wild Cats	10
Portraits	17		
		Ships	11
Ships	23		
		Food items	14

and chimpanzees, monkeys and humans, respectively (Table 2). All natural categories were learned with a minimum of 4 and a maximum of 14 trials (median value), whereas all categories of man-made objects were learned with a minimum of 8 (portraits for M2) and with a maximum of 23 trials. A surprising similarity for both animals was the difficulty to learn the category of food items that during the learning phase consisted of fruit only (10 trials for M1, 14 trials for M2). A possible reason for this might be the fact that fruit images often included leaves, another source of food for the monkeys, which consisted a separate category mapped on the opposite lever. A second possible explanation is that, in contrast to the rest of the categories, food items was a superordinate category, including a variety of basic fruit types (e.g. bananas, apples). There is evidence that monkeys encode this category by type of fruit (i.e. at the basic level) [13], therefore it may have been more difficult for them to form the more abstract, superordinate fruit category. The fact that it was one of the last categories that were introduced to the monkeys might also have played a role, although the categories that were presented immediately before them were learned faster (gorillas for M1 with 6 trials, and orangutans for M2 with 7 trials). An interesting difference between the two monkeys was that they showed a somewhat individual preference or difficulty while learning the different categories. For example, the category Wild Cats was one of the 5 easiest for M1, but one of the 4 most difficult for M2. This finding supports the idea that the ability to associate pictures and objects may not be uniformly distributed within a group of subjects and may depend on individual factors [10, 14, 15], cf. [16] for differences in categorization of conspecific pictures between the two animals.

The effect of familiarity that was observed during the learning phase could be interpreted as evidence that the monkeys perceive the stimuli presented on the computer screen as representations of objects they encounter in their everyday life. This result is in agreement with other studies that report successful categorizations of natural categories, like animals and trees, e.g. [7, 8], and recognition of photographic representations of objects with experience [17]. Moreover, the observation that as few as 4 pictures suffice for the monkeys to form an adequate category representation of objects they have never experienced in their life is novel. This also seems to be the case for objects that the monkeys (or any other animal) are not expected to be genetically disposed to recognize (i.e. ships, buses, airplanes). This result is in agreement with the reported ability of untrained infant monkeys to categorize scale models of animals and furniture [18]. Both animals were just as fast and accurate at generalizing to new examples of man-made objects, suggesting that they are able to extract similarities and form equivalence

classes, from a small number of stimuli differing widely across size, color and viewpoint, and for which they have no prior internal representation.

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