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SAMENESS-DIFFERENCE JUDGMENTS OF NUMEROUSNESS BY MONKEYS: *MACACA MULATTA* AND *MACACA ASSAMENSIS*

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ABSTRACT: Three of four monkeys were trained successfully on a series of number-related judgment problems ending with "same" and "different" judgments involving pairs of numerosness discriminanda. The discriminanda were black "dots" drawn on cards and constructed using controls to preclude the use of cumulative area or brightness cues and to make specific pattern memorization unlikely. On the final task, all possible same and different pairs of discriminanda representing the numbers 2 through 6 were used, and three monkeys met criterion (two successive sessions of 80% or more correct) in 80, 160, and 200 trials, respectively. Discussion considered possible underlying processes to explain the numerosness judgments as well as the implications of the present work for Piaget's views on conservation of quantity.

The numerical competence of animals has long been of interest (e.g., Honigman, 1942; Salnan, 1943; Wesley, 1961; Davis & Memmott, 1982; Davis & Pérusse, 1988). However, concerning the early work, Wesley concluded that only Hicks' (1956) study of rhesus monkeys' (*Macaca mulatta*) ability to respond to "threeness" had been sufficiently free of confounding to show animals' use of number-related cues. Subsequently, several suitably controlled investigations have been reported; see Davis & Pérusse, 1988, for examples. In terms of well-controlled, fully-reported published studies, Thomas, Fowlkes, and Vickery's (1980) report that squirrel monkeys (*Saimiri sciureus*) can distinguish seven from eight entities ("dots") appears to have shown the possible upper limit of noncounting-based numerosness discrimination by animals. More recently, Terrell and Thomas (in press) also using squirrel monkeys, have shown a similar upper limit

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when the number-related discriminanda were the number of sides (or angles) of randomly constructed polygons. Most recently, Thomas, Phillips and Young (personal communication, August 13, 1990) have reported possibly similar upper limits for humans (*Homo sapiens*) using both dots and polygons as discriminanda.

The present study was suggested by the numerosness judgment capacity concept developed by Thomas and his colleagues (Czerny & Thomas, 1975; Thomas et al., 1980) and by previous investigations (Lin & Gong, 1989; Zhang, 1989). The use of numerosness discriminanda was extended to a new conceptual context, namely, whether monkeys can use such discriminanda to make "same" and "different" judgments. In addition to the implications of such judgments in terms of the concepts of same and different *per se*, such judgments have relevance to Piaget's views concerning the conservation of number.

METHODS

Animals

Three rhesus monkeys (*Macaca mulatta*) and one Assamese macaque (*Macaca assamensis*) were used as the subjects. The rhesus monkeys were: (a) Jia-jia, a laboratory-born female, 5 years old at the beginning of this experiment. She had received training involving numerosness discriminanda approximately two years prior to the present study and involving the use of numerosness concepts approximately one year before the present study; (b) Mei-ling a laboratory-born female, 1.67 years old when the experiment began which had no prior numerosness training; and (c) Dou-dou a wild-born female, 2 years old who was bought from the Beijing zoo for the present study. The Assamese macaque, Xiao-shan, was a laboratory-born male, 2 years old, with no prior research experience.

Apparatus and General Procedure

A modified Wisconsin General Test Apparatus, painted dark gray, was used. Within the testing apparatus, two stimulus-presentation boxes (12 x 14 x 15 cm) also painted gray were used. During testing the boxes were placed 3 cm apart. A colorless transparent glass of 12 x 14 cm was mounted in the front of each stimulus presentation box, and a stimulus card could be displayed behind the glass and in front of the box. Below each box, there was a food-well to hold the reinforcers.

When the experiment began, the animal was transported to a testing cage (35 x 40 x 50 cm) which was juxtaposed against the front

of the testing apparatus. A screen that could be raised and lowered was placed between the testing apparatus and the testing cage. At the beginning of each trial, the screen was lowered to prevent the monkey from seeing the experimenter place the discriminanda in their glass holders and the reinforcer beneath the appropriate stimulus presentation box. The screen was then raised to display the discriminanda, and the whole apparatus was pushed towards the animal and within its reach to allow it to make a response. Following the response, the screen was lowered to enable the experimenter to set the discriminanda and reinforcer for the next trial. In order to make a response and gain the reinforcer, the monkey could push aside the stimulus presentation box associated with the correct discriminandum for that trial. Incorrect responses were not reinforced, and the stimulus presentation boxes were withdrawn to prevent the monkey from correcting its response.

Discriminanda

The discriminanda were black-filled circles (hereafter, these will be referred to as “dots”) that were drawn on white cards. The cards were 11.5 x 13 cm and from 2 to 6 black circles were drawn on each card. In order to control against the use of the dots’ cumulative areas as discriminative cues or the differential brightness cues resulting from the cumulative area of the black dots, the areas of the circles were varied. Three diameters of black circles were used, 2.5 cm, 1.9 cm and 1.4 cm, and these were selected quasi-randomly for the construction of each card. In order to avoid a fixed pattern or repeated patterns in the construction of the discriminanda, a 16-point (4 x 4) grid was used to determine the loci of the black circles on the cards; the placement of the dots on the grid was determined quasi-randomly. Each number from 2-6 was represented by 25 individually constructed cards and each card might be displayed in the upright or inverted position; therefore, each number was represented by 50 discriminable patterns. The left-right position of a given card in conjunction with the two stimulus-presentation boxes was determined randomly.

Training Procedures

Initially, the monkeys were exposed to the experimenter and apparatus in order to let the animals become habituated to the handling required, the experimenter, and the general demands of the experimental situation. The following six tasks were used in the order listed. Each animal was trained on each task until it met a criterion of 80% or greater accuracy for two successive days or until it was judged that the animal was unlikely to attain criterion.

1. *Discrimination training: 3 vs. 5.* The purpose of using the first task was to get the animal to discriminate between exemplars of the numbers 3 and 5. Responses to the discriminanda with 5 dots were reinforced.

2. *Discrimination training to respond to "more" using pairs constructed of cards with 2, 4 or 6 dots.* Responses to the card with more dots in each pair of numbers were reinforced.

3. *Discrimination training to respond to "more" using pairs constructed of cards with 2, 3, 4, 5, or 6 dots.* This task was similar to the preceding task except that cards with 3 and 5 dots were also used.

4. *Sameness-difference pretraining.* This pretraining task introduced the possibility of having the subject learn to respond by using "same" and "different" numerosness judgments. To represent "different," one card with 3 and another card with 5 dots were used and to represent "same," a pair of cards, each with 3 dots was used. When the stimulus pair 5-3 was displayed, the number 5 was always displayed on the left and the reinforcer was available when the monkey responded to the "5" card on the left. When a same-pair (3-3) was presented, reinforcement was available when responses were made to the "3" card on the right. In quasi-random order, 20 "same" and 20 "different" trials were presented each day. It was realized that solutions other than responding to "same" or "different" were possible. For example, the monkeys merely had to learn to respond to "5" when it was available and to the "3-on-the right" when "5" was not available. However, as a form of pretraining for same and different numerosness judgments, it was believed that this was a useful procedure with which to begin.

5. *Sameness-difference training using cards with 2, 4, or 6 dots.* The difference-pair discriminanda consisted of 6-4, 6-2, and 4-2 dots, and the same-pair discriminanda consisted of 6-6, 4-4, and 2-2 dots. These six stimulus pairs were presented in quasi-random order so that each stimulus pair appeared approximately equally often during each day's 40-trials session; that is, each pair was presented 6 or 7 times daily. Correct responses to a "different-pair" were denoted by responding to the card on the left and correct responses to a "same-pair" were denoted by responding to a card on the right.

6. *Sameness-difference training using cards with 2, 3, 4, 5, and 6 dots.* The difference-pairs were 2-3, 3-4, 4-5, 5-6, 2-4, 3-5, 4-6, 2-5, 3-6, and 2-6 and the same-pairs were 2-2, 3-3, 4-4, 5-5, and 6-6. Twenty same and 20 different pairs were presented in quasi-random order during each session. However, selection among the 10 different-pairs was also in quasi-random order to insure that it was likely that the easier (e.g., three or four numbers apart) and harder (e.g., one or two numbers apart) difference-pairs occurred equally often during a session.

TABLE 1
Trials to Criterion (TC) and Mean Percentage Correct (%)
During the Criterion Sessions for the Three Successful
Monkeys on the Six Tasks

<i>Measures</i>	<i>Subjects</i>					
	<i>Mei-ling</i>		<i>Jia-jia</i>		<i>Xiao-shan</i>	
	<i>TC</i>	<i>%</i>	<i>TC</i>	<i>%</i>	<i>TC</i>	<i>%</i>
Tasks						
1	920	85	580	88	506	88
2	80	80	100	83	60	90
3	120	81	60	82	60	85
4	230	83	320	86	180	85
5	120	84	210	87	60	82
6	200	84	160	88	80	81

RESULTS AND DISCUSSION

Three of the four monkeys reached the 80% criterion on all tasks. For the three successful monkeys, trials to criterion and average percentages correct in the two sessions used to define criterion may be seen in Table 1. One of the rhesus monkeys (Dou-dou) failed to reach criterion in 1,155 trials on the first task, and her training was terminated.

As shown in Table 1, the monkeys acquisition of Task 1 required the most trials of any of the six tasks. There was evidence of strong transfer of training from Task 1 to its related Tasks, 2 and 3. Same-different training was introduced in Task 4, and its acquisition was accomplished in fewer than half the trials taken by the best monkey on Task 1. These data suggest strong general transfer of training among the numerosness tasks regardless of whether numerosness discrimination or same-different numerosness judgments were required. In view of the number of unique discriminanda used together with the relatively few trials to criterion on Tasks 2-5, it appears that the monkeys were responding to numerosness on a conceptual basis.

GENERAL DISCUSSION

Six tasks were used in the present research. The first three involved numerosness discrimination judgments and the last three involved numerosness judgments based on "same" and "different." That three of the four monkeys were highly successful on all six tasks

indicates that numerosness judgments are well within the capacity of the genus, *Macaca*.

Davis and Pérusse (1988) suggested several possible processes that nonhuman animals might use to make numerosness judgments. However, Terrell and Thomas (in press) and Thomas and Lorden (in press) have argued that only two processes can account for all reports of animals' use of number, namely, counting or prototype matching. They noted that counting is controversial and that the evidence for counting depends on the definitions and criteria that one uses. They suggested that many investigators appear to agree that evidence for Gelman and Gallistel's (1978) first three principles is necessary (viz., *one-to-one correspondence* between counting "tags" or symbols and items to be counted; the application of the tags in *stable-order*; the *cardinal principle* according to which the last tag applied defines the number of items in the counted set) and they questioned whether such evidence had been shown sufficiently in any animal study. They also suggested that the prototype matching interpretation could explain any animal research on numerical competence to date. According to the prototype matching interpretation, a subject acquires through experience an average representation (or prototype) of sets of items representing particular number categories; these average representations may be precise (e.g., "threeness," "sevenness," etc.) or imprecise (e.g., "manyness") and may be used in numerosness judgments on an absolute (e.g., "threeness") or relative (e.g., "more" or "fewer") basis. Applied to the present work, the acquisition of numerosness concepts on a prototype matching basis underlies both the discriminative and same-different numerosness judgments. Same-different judgments also superimpose a second kind of category judgment on the required numerosness judgments.

While Piaget is usually remembered as being a developmental psychologist, it is clear from his writings that he viewed himself as being a constructive epistemologist. Piaget's research tended to address the ontogenetic development of cognitive structures and skills in children, but he made it clear (e.g., Piaget, 1971) that he viewed his work in phylogenetic contexts as well.

Recent reviews of the animal-Piagetian research have reached widely different conclusions. Thomas and Walden (1985) expressed a conservative view and suggested that the two most studied concepts in animals, object permanence and conservation, pose fundamental problems that may not be addressable using animals (e.g., they argued that linguistic explanations may be essential in the evidence for conservation). However, Doré and Dumas (1987) were much less critical of the animal-Piagetian research. Doré and Dumas cited Thomas and Walden, but it appeared that they had not considered fully the objections raised by Thomas and Walden.

In any event, the successful same-different numerosness judgments shown in the present study appear to be related directly to an argument presented by Piaget (1968) concerning the evidence for the conservation of number, and we deem it to be useful to present our findings in this context. Commenting on a study by Mehler and Bever (1967), Piaget (1968) argued:

. . . conservation of equality . . . can be shown only if two rows of equal numbers are presented and one row is then spread out or crowded; or at least if two rows of unequal length are presented without modification (p. 978).

Our evidence for “same” judgments of numerosness (the “different” judgments in this case served as controls to insure that the subject was judging same and different differentially) appears to be more rigorous than the evidence described by Piaget in his comment on Mehler and Bever as being the “least” required to show conservation of equality. In Mehler and Bever’s case, the entities were the same size permitting confounded judgments of *equivalence* based on cumulative area or volume cues. Equivalence in our case can be based only on numerosness, as the sizes of the entities were varied.

In terms of conservation, the issue that remains to be resolved is whether the judgments in our study reflect the monkeys’ abilities to perceive the perceptual equivalence of numerosness discriminanda as opposed to the conservation of number. A liberal interpretation is that we have provided evidence for conservation that is more rigorous than the minimal evidence that Piaget himself said was required. A conservative interpretation is that resolution of the distinction between perception judgments of equivalence and the true conservation of number requires the subject’s verbal explanation, as Thomas and Walden (1985) have argued. The resolution of this issue is beyond the scope and means of this article to provide. In any case, it is reasonable to say that the present research provides good evidence for essential prerequisites to the conservation of number if not for the conservation of number itself.

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