

ON THE LIMITS OF THE MATCHING CONCEPT IN  
MONKEYS (CEBUS APELLA)

M. R. D'AMATO AND MICHAEL COLOMBO

RUTGERS—THE STATE UNIVERSITY

Two cebus monkeys, with many years of experience matching a variety of static visual stimuli (forms and colors) within a standard matching-to-sample paradigm, were trained to press a left lever when a pair of displayed static stimuli were the same and to press a right lever when they were different. After learning the same/different task, the monkeys were tested for transfer to dynamic visual stimuli (flashing versus steady green disks), with which they had no previous experience. Both failed to transfer to the dynamic stimuli. A third monkey, also with massive past experience matching static visual stimuli, was tested for transfer to the dynamic stimuli within our standard matching paradigm, and it, too, failed. All 3 subjects were unable to reach a moderate acquisition criterion despite as many as 52 sessions of training with the dynamic stimuli. These results provide further evidence that, in monkeys, the matching (or identity) concept has a very limited reach; they consequently do not support the view held by some theorists that an abstract matching concept based on physical similarity is a general endowment of animals.

*Key words:* matching concept, cognitive processes, matching to sample, same/different procedure, monkeys

An abstract representation of the identity concept is a cognitive characteristic of humans so basic that it passes almost unnoticed. Indeed, recognizing the identity of objects subjected to various transformations is thought to play a fundamental role in the early cognitive development of infants (Caron & Caron, 1982, pp. 118-120), forming an important part of the cognitive substrate that supports more complex conceptual structures (Bower, 1974).

Comparative psychologists have long been interested in the degree to which the identity concept is represented in animals (e.g., Nissen, Blum, & Blum, 1948; Weinstein, 1941). A variety of mammalian and nonmammalian species are capable of learning tasks in which the subject, presented with two or more alternatives, must respond to that one which matches a sample stimulus—the matching-to-sample paradigm. But having learned to match a small set of specific stimuli, has the animal simultaneously acquired something more general—the identity, or matching, concept?

According to Premack (1983b), the matching concept based on physical similarity is widespread among animals: "The reaction to similarity, to the likeness between the ap-

pearance of things, is found both in primates and nonprimates . . . [It is] abstract, widely distributed over species, and independent of special experience" (p. 135). It is of interest to note that this position was anticipated by Nissen (1953), who found "an explanation for simple and generalized matching" in the supposition that "the perception of identity and difference [is] basic and universal in animal behavior" (p. 282).

We view the matter somewhat differently. For one thing, the available evidence indicates to us that among those species capable of learning to match stimuli on the basis of physical likeness, representation of the matching concept varies enormously. Monkeys, for example, seem to possess this conceptual capacity to a much greater degree than do pigeons (see D'Amato, Salmon, & Colombo, 1985; Wilson, Mackintosh, & Boakes, 1985a, 1985b). For another, rather than being abstract, the matching concept, as manifested by many species, has a distinctly limited embrace. Monkeys well versed in matching a variety of visual stimuli fail to transfer their matching behavior to acoustic stimuli and, indeed, are often unable to learn to match such stimuli (D'Amato & Colombo, 1985). Transfer of matching from the visual modality to touch has also been found wanting (Milner, 1973).

More surprising, within the visual modality we found that monkeys who displayed evidence of the matching concept after experience

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with as few as two exemplars failed to transfer their matching behavior to a different class of visual stimuli (D'Amato et al., 1985). Initially trained and tested with simple forms or a red disk (static visual stimuli), these subjects were unable to transfer their matching behavior to a sample set consisting of flashing and steady green disks (dynamic visual stimuli); indeed, they demonstrated little, if any, savings in learning to match the latter stimuli. Results from control subjects showed that the difficulty was not due to poor discriminability of the dynamic stimuli. Interestingly, after having learned to match two different pairs of dynamic stimuli, the monkeys showed a high level of transfer to a third set, as though they had to acquire the matching concept anew with the dynamic stimuli.

The monkeys' failure to transfer matching from static to dynamic visual stimuli is especially damaging to the view that the matching concept based on physical likeness is widely represented in animals in an abstract form. Inasmuch as the matching concept is perhaps the most elemental of relational concepts, this finding also has important implications regarding the degree of abstractness one can expect to find in animals for other relational concepts. In view of the potential significance of the results of D'Amato et al. (1985), their generality is an important issue.

One possible limitation of the D'Amato et al. (1985) study is that the subjects had only a limited amount of experience matching static visual stimuli, based on a total of only four to eight exemplars. This raises the question of whether prolonged experience matching a much wider variety of static visual stimuli might develop a more abstract matching concept and thus promote transfer to dynamic exemplars. A second consideration is that the conventional matching-to-sample paradigm employed by D'Amato et al. and other investigators may be deficient in encouraging the development and expression of a general matching concept. The animal's task is simply to respond to the comparison stimulus that matches the sample stimulus. As a consequence, there is no unique response unrelated to the discriminative stimuli that defines, and therefore can become associated with, the property of sameness. Also, the standard matching procedure is asymmetrical, in that only a matching response is required (and reinforced). This asymmetry may discourage

the formation of matching/nonmatching categories, further restricting the generality of the matching concept (Edwards, Jagielo, & Zentall, 1983).

Combining both of these concerns, in the present study 2 monkeys with many years of experience matching a variety of static visual stimuli in a conventional matching-to-sample paradigm were trained to make one response (pressing a left lever) if a pair of stimuli were the same and a different response (pressing a right lever) if they were different. A sample set of five static stimuli was employed, generating 15 comparison pairs. The subjects were then tested for transfer to the same pair of dynamic stimuli used by D'Amato et al. (1985), that is, flashing versus steady green disks. If the scope of the monkeys' matching concept had been broadened either by their extensive past matching experience with many exemplars or by providing them with unique responses for same and different, a substantial degree of transfer to the dynamic stimuli should be observed.

We will use the term *same/different procedure* to refer to situations in which separate *same* and *different* responses, unconnected with the discriminanda, are available for indicating the similarity status of simultaneously present target stimuli. Excluded from our definition are *same/different* discrimination (e.g., Robinson, 1955) and related procedures (e.g., Burdun & Thomas, 1984; Czerny & Thomas, 1975; King & Fobes, 1975) in which the subject's response is directed to one or both of the pair of stimuli being judged. The term *matching procedure* will be reserved for conventional situations that incorporate sample stimuli and in which the subjects respond to the target stimuli themselves. Maintaining this distinction, the conceptual capacity demonstrated within the *same/different* paradigm will be referred to as the *same/different concept*.

Edwards et al. (1983) attempted to train pigeons on a *same/different* procedure with one pair of exemplars and then demonstrate that the birds could transfer the *same/different* training to a new pair of stimuli. They concluded that the pigeons had used the same and different responses (pecking side panels) symbolically to represent the corresponding concepts, in a manner similar to that of language-trained chimpanzees. As discussed in more detail elsewhere (D'Amato et al., 1985), because only three of the four possible *same/*

different stimulus configurations were used during training and testing, there is little reason to believe that the pigeons learned the initial task on the basis of same/different judgments, let alone that they developed a same/different concept.

Employing color slides of a variety of items, including people, Santiago and Wright (1984) reported same/different learning in pigeons that extended to a serial probe recognition task based on as many as six list items. However, because exactly the same sequence of list and probe items were used in every training session given with a fixed list length, it is highly doubtful that their subjects' performance was based on same/different judgments. Indeed, the generally low level of transfer obtained with novel stimulus pairs, even after several exposures (see their Table 2), strongly suggests that the pigeons' acquisition of the basic same/different task lacked a conceptual component. Monkeys, on the other hand, do seem capable of same/different learning, although not without a very substantial amount of training (e.g., Sands & Wright, 1980).

## METHOD

### *Subjects*

Three female and 1 male (Roscoe) New World monkeys (*Cebus apella*) served as subjects. Coco, Olive, and Roscoe, wild-born monkeys who were 24 or 25 years of age at the start of the study, had massive amounts of previous experience with simultaneous and delayed identity matching, distributed over more than 15 years. They had learned to match at least a dozen different two-dimensional forms and colors, and all 3 had extensive experience matching compound samples (e.g., vertical line superimposed on a red disk) to comparison stimuli consisting of only one component of the compound (Cox & D'Amato, 1982). We refer to these types of stimuli as *static* because their properties remain constant over a trial; stimuli whose defining properties include a temporal component are referred to as *dynamic*. None of the 3 monkeys had any experience with dynamic visual stimuli.

Jane, a laboratory-born monkey 9 years of age, had served in the D'Amato et al. (1985) study and thus had already learned to match the flashing versus steady green dynamic stimuli. She subsequently received about 21 months of additional matching experience with visual

dynamic stimuli, including flashing and steady green, that ended 2 years before the beginning of the present study. Her role in the experiment is discussed below.

The monkeys were housed in individual cages with ad lib access to water. Food (Purina Monkey Chow® 5045) was restricted to a single feeding delivered 2 to 3 hr following an experimental session, in an amount that supported reliable performance. The daily rations were sufficient to maintain the monkeys at about 90% of their free-feeding body weights.

### *Apparatus*

The apparatus was the same as that used by D'Amato et al. (1985). Briefly, the front panel of a monkey operant chamber housed five inline stimulus projectors, located at the four corners and center of a 12-cm square. Each projector was fitted with a transparent plastic key that served as the response mechanism. Located below the projector array was a microswitch that, when activated, initiated a trial. Two response levers, separated by 43 cm, were situated at the same level as the bottom edge of the projector array. Display units directly above the levers could be illuminated, indicating that the levers were operable. Noyes 190-mg banana-flavored food pellets served as reinforcers and were delivered to a receptacle located on the right wall. Chamber illumination was provided by an overhead houselight that could be dimmed by adding a 500-ohm resistor in series with the bulb.

The static stimulus set consisted of red disk, circle, dot, vertical line, and hourglass (an inverted triangle superimposed on an upright triangle). A green disk, that either was steady or flashed at a rate of about 3.85 Hz with 100-ms on times and 160-ms off times, comprised the dynamic stimulus pair. The red and green disks were 25 mm in diameter; the forms appeared as a white figure on a black background and, except for the circle and the dot, were composed of lines 1.5 mm wide by 17 mm long. The circle, also composed of a 1.5-mm wide line, was 17 mm in diameter, and the solid dot was 6 mm in diameter.

### *Procedure*

*Experimental design.* To obtain information regarding both of the variables that concerned us, the 3 monkeys with extensive past matching-to-sample experience were deployed as follows. Coco and Roscoe were first given same/

different training with static stimuli and then tested for transfer to dynamic stimuli within the same paradigm. Obviously, if these subjects produced positive results, it would be unclear as to whether such a result should be attributed to the monkeys' very extensive past matching experience or to the same/different training (and testing). To aid in disentangling the two variables, the other monkey with extensive past matching experience, Olive, was denied same/different training and was tested for transfer to dynamic stimuli within the standard matching-to-sample paradigm. Positive results from Olive would point to past matching experience as the critical variable, whereas failure to transfer would implicate same/different training (and testing) as the relevant factor.

Jane, like Coko and Roscoe, was given same/different training with static stimuli and then tested for transfer to the dynamic stimuli. The point at issue was whether her ability to match dynamic stimuli, previously acquired within our conventional matching procedure, would survive the transition to the same/different paradigm. Failure to transfer would indicate that, as suggested by Premack (1983a), the two paradigms tap different processing mechanisms.

*Same/different training.* The final same/different procedure was reached through three stages of training, which will be referred to as *successive*, *simultaneous*, and *five-key same/different* (S/D) training. In successive S/D training, activation of the microswitch four times (fixed-ratio, FR, 4) resulted in the sample stimulus appearing on the lower right projector; a response to the sample key was followed by presentation of the comparison stimulus on the lower left projector, with the sample still present. In early sessions with the first sample set the subject was required to press the comparison stimulus key within 3 s if it matched the sample and refrain from pressing for the same duration if it did not. During all subsequent sessions the two side levers became operable (signaled by illumination of the display units above the levers) when the subject pressed the sample key; now the correct response on matching trials was to depress the left lever, whereas on nonmatching trials pressing the right lever was correct.

Simultaneous S/D training differed only in that an observing response on the sample key was no longer required; upon completion of

the FR 4 on the microswitch, a matching or a nonmatching stimulus configuration was presented on the lower two projectors and the two side levers became operable. Five-key S/D training was the same as simultaneous S/D training, except that the stimulus configurations were no longer restricted to the lower two projectors and now appeared with equal probability on any two of the five projectors.

Six sample sets were used in the first two phases. The first sample set consisted of the circle and the vertical-line stimuli; this set was followed by circle and dot, by vertical line and dot, and then by the three-sample set of circle, vertical line, and dot. Red disk and hourglass comprised the fifth sample set, and all five stimuli composed the final, five-sample, set. For all sample sets, every possible matching and nonmatching configuration was presented, with equal numbers of matching and nonmatching trials in each session. For the first five sample sets, the subjects were trained until they met the minimum criterion of 86% correct responses in a single session of 36 trials; the criterion for the sixth sample set was at least 80% correct in a single session of 40 trials.

The first sample set of five-key S/D training was also circle and vertical line. After reaching the 86% correct criterion in a single 36-trial session, the subjects were presented with the five-sample set. Training on the latter was continued until the stringent criterion of two consecutive sessions with at least 90% correct responses was reached or until 20 40-trial sessions were completed.

A typical simultaneous (or five-key) S/D training trial proceeded as follows. After termination of the 20-s intertrial interval (ITI), a trial was initiated by completion of the FR 4 on the microswitch, which caused a matching or nonmatching stimulus pair to be presented on the lower two (or any two) of the five projectors and illumination of the display units above the side levers. A correct response, pressing the left lever on matching trials and the right lever on nonmatching trials, was reinforced with one food pellet, after which the ITI was entered. Incorrect responses resulted in a 1-min timeout, signaled by dimming of the houselight, with the ITI following the timeout.

*Matching-to-sample training.* The matching procedure differed from the S/D paradigm in that completion of the FR 4 on the microswitch

Table 1

Numbers of sessions to the acquisition criterion in the three phases of same/different (S/D) training with the different sample sets (a-f).

Subject	Successive S/D						Simultaneous S/D						Five-key S/D	
	a	b	c	d	e	f	a	b	c	d	e	f	a	f
Coco	8	3	1	3	1	1	2	1	1	1	2	1	3	20*
Roscoe	25	3	7	2	4	1	21	2	3	2	1	1	35*	20*
Jane	8	1	6	1	1	2	11	2	11	2	4	1	14	13

Note. a = circle/vertical line, b = circle/dot, c = vertical line/dot, d = circle/vertical line/dot, e = red/hourglass, and f = all five stimuli.

\* Subject did not satisfy criterion with this sample set.

resulted in presentation of the sample stimulus on the center projector. When the center response key was pressed, the two comparison stimuli appeared on (any) two of the four outer projectors, with the sample still present on the center projector. The consequences of correct (pressing the matching comparison stimulus) and incorrect (pressing the nonmatching comparison stimulus) responses were the same as with the S/D procedure.

Because of her previous extensive matching experience, Olive was given training with only three sample sets: the circle and vertical line, the red disk and hourglass, and the same five-sample set presented to the other 3 subjects. The accuracy criteria used in S/D training were also applied to Olive.

*Transfer testing.* The same paradigm was used in testing as in training, S/D for Coco, Roscoe, and Jane and matching to sample for Olive. Following D'Amato et al. (1985), in all cases transfer testing consisted of four 48-trial sessions. On half of a session's trials the stimuli to be matched were the familiar static stimuli, circle and vertical line; on the other, critical, 24 trials they were the dynamic stimuli, flashing versus steady green disks. The transfer criterion was the same as used by D'Amato et al. (1985): at least 70.8% (17/24) correct responses with the dynamic stimuli on each of the last three transfer sessions. The one-tail probability of achieving such a result by chance is less than .0001.

Transfer testing was followed by 48-trial acquisition sessions, based only on the dynamic stimuli. Acquisition training was planned to continue until the criterion of one session with at least 90% correct responses was met; however, the experiment was terminated for 3 of the 4 subjects before they achieved that performance level.

## RESULTS

*Acquisition.* Table 1 summarizes the acquisition results for the 3 monkeys trained on the S/D procedure. After acquisition of the first sample set, training on successive S/D was completed rather rapidly, requiring a total of only from 9 to 17 sessions for all five sets. Note that although the subjects had not previously encountered red disk and hourglass in the S/D paradigm, Coco and Jane transferred immediately to this sample set.

Surprisingly, Roscoe and Jane had considerable difficulty in shifting to the simultaneous S/D procedure, which, as will be recalled, differed only in that an observing response on the sample key was no longer required to produce the comparison stimulus and enable the response levers. Once this hurdle was surmounted, the subjects progressed rapidly, except that Jane had difficulty with the vertical line/dot sample set. Transfer to the red/hourglass sample set was again rapid for 2 of the monkeys, and all subjects required only a single session to reach the 80% correct criterion with the five-sample set.

Also surprising was the fact that the performance of Roscoe and Jane deteriorated badly when the circle/vertical line stimuli, with which the monkeys had so much S/D experience on the lower two projectors, were presented on any two of the five projectors. Jane required 14 sessions to reach criterion (86% correct) after the institution of this seemingly small change, and despite special training on pairs of projectors that appeared to present special problems to Roscoe, he was unable to reach criterion within the 35 sessions allotted him.

Because we wanted the subjects to enter transfer testing with a high level of compe-

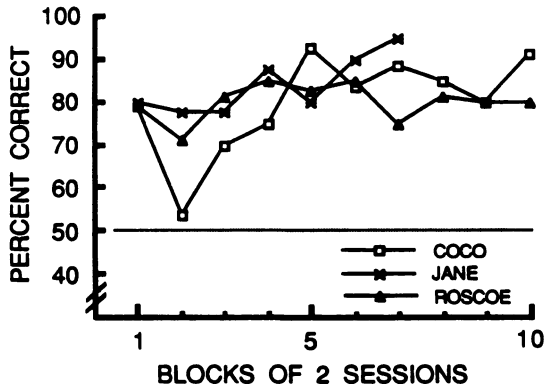


Fig. 1. Percentages of correct responses, in blocks of two 40-trial sessions, during five-key same/different training with the five-sample set. Jane reached the acquisition criterion (two consecutive sessions with at least 90% accuracy) on the 13th session.

tence in the five-key S/D task, the criterion applied to the five-sample set was stringent, at least 90% correct in two consecutive sessions. Only Jane, who averaged 95% correct responses on the two criterial sessions, met the criterion. However, as Figure 1 shows, over her last 12 sessions Coco usually performed at a high level, averaging 91.3% correct responses on the final two sessions. (Her sharp performance decline in the second block of trials is most likely due to the fact that the intensity and distribution of the illumination of the display units above the levers were changed on Session 3, a modification that occurred much earlier for the other 2 subjects.)

Although Roscoe scored 90% correct on three earlier nonconsecutive sessions, his performance during the last six sessions (Figure 1) departed little from 80% correct. In three subsequent sessions during which only the lower two projectors were used, he averaged 94.2% correct responses. Consequently, only these projectors were used during transfer testing.

In the standard matching-to-sample task, Olive required one session to reach criterion with the circle/vertical line sample set, and only two sessions each with red disk/hourglass and the five-sample set. In the second session with the last sample set she scored 100% correct responses.

*Transfer testing.* Jane had not encountered visual dynamic stimuli for 2 years; nevertheless, she easily met the transfer criterion of at least 70.8% correct responses on each of the

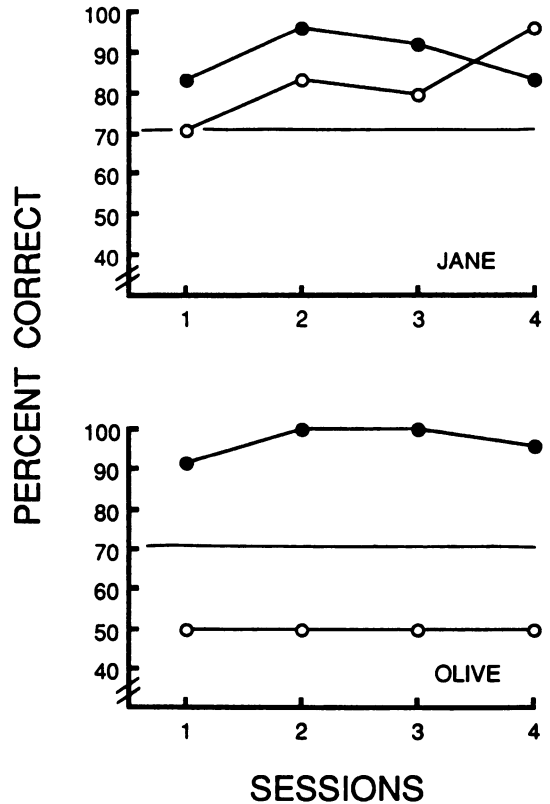


Fig. 2. Percentages of correct responses during the four 48-trial transfer sessions, with half of the trials based on the old stimuli (filled circles) and half on the new (unfilled circles). Circle/vertical line comprised the old, static, stimuli; the new, dynamic, stimuli were flashing/steady green disks. Jane was tested with the same/different procedure, Olive with the standard matching-to-sample paradigm. Jane, who previously had learned to match the dynamic stimuli within the matching-to-sample paradigm, satisfied the criterion for concept-mediated transfer, which was a response accuracy of at least 70.8% (thin solid line) on Sessions 2, 3, and 4.

last three transfer sessions (Figure 2, upper panel). During the last session, her performance with the dynamic stimuli exceeded that achieved with the baseline static stimuli.

The results obtained from the other 3 subjects were quite another matter. Olive's data, which also appear in Figure 2 (lower panel), hardly require comment. Although she maintained a high accuracy level on the baseline static stimuli, her matching-to-sample performance with the flashing and steady green disks never exceeded chance. Nor was her chance performance due to an exclusive preference for one of the dynamic comparison stimuli. Olive

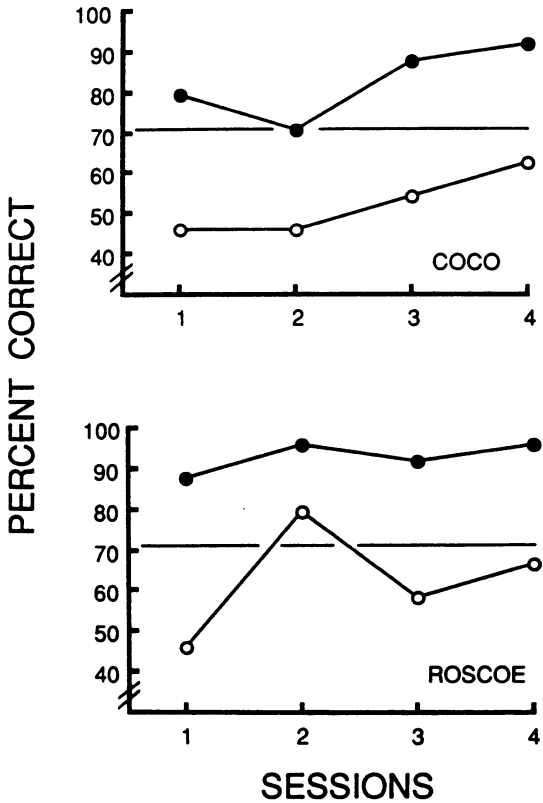


Fig. 3. Percentages of correct responses during the four 48-trial transfer sessions, with half of the trials based on the old stimuli (filled circles) and half on the new (unfilled circles), which were the same as in Figure 2. Both monkeys were tested with the same/different paradigm; neither met the criterion for concept-mediated transfer of at least 70.8% correct responses (thin solid line) on Sessions 2, 3, and 4.

was correct on 44% of the trials in which steady green served as the sample stimulus compared to 56% when the sample was flashing green.

The 2 monkeys trained and tested with the S/D procedure fared little better. Figure 3 shows that only on one occasion did performance with the flashing and steady green disks reach the criterion level. In short, neither Olive nor the 2 monkeys tested with the S/D procedure came close to satisfying the transfer criterion. Their performance levels with dynamic stimuli were very similar to those reported for monkeys who had far less experience matching static stimuli (D'Amato et al., 1985, Figure 4).

The acquisition data were perhaps even more telling. Jane required only eight sessions

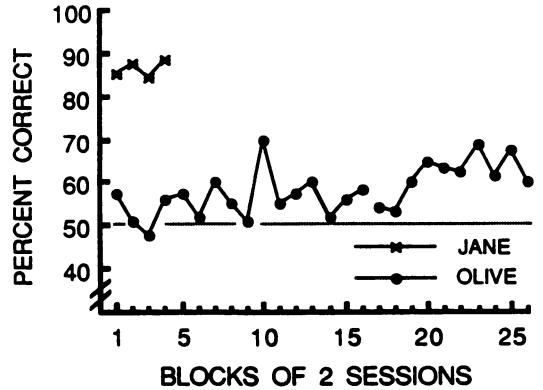


Fig. 4. Percentages of correct responses, in blocks of two 48-trial sessions, during acquisition training with the dynamic stimuli (flashing/steady green). Jane, trained with the same/different procedure, met the acquisition criterion of one session with 90% or more correct responses on Session 8. Olive, trained with the matching-to-sample paradigm, failed to reach criterion within the allotted 52 sessions; this subject received 16 sessions of training with compound samples, interposed between Sessions 32 and 33 (see text).

to meet the acquisition criterion of at least 90% correct responses in one 48-trial session, and as Figure 4 shows, her performance was quite respectable throughout acquisition, averaging 86.5% correct over the eight sessions.

In sharp contrast, although allotted 52 training sessions, Olive failed to reach criterion (Figure 4), her matching performance never exceeding 73% correct in a session. Nor were the S/D trained monkeys any better. Coco also failed within 52 sessions to meet the 90% criterion (Figure 5), her maximum performance in a single session reaching only 77% correct. And as shown in Figure 5, Roscoe's performance was not much better than chance at the 40th session when, because of time limitations, the experiment was terminated.

By way of comparison, the mean number of sessions required by the 4 subjects of the D'Amato et al. study (1985, Experiment 2) to learn to match flashing and steady green to the criterion of two consecutive sessions with 90% or more correct responses was 28.5. The worst score, posted by Jane, was 44 sessions, well below the 52 allowed Coco and Olive.

In an effort to improve Olive's performance with the dynamic stimuli, after the 32nd training session she was given 16 40-trial sessions matching a variety of compound static stimuli. In the last eight of these sessions, one com-

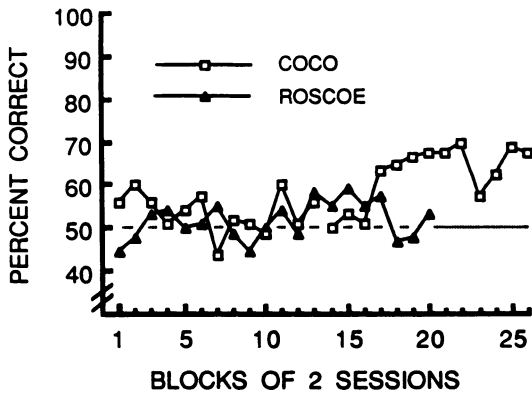


Fig. 5. Percentages of correct responses. In blocks of two 48-trial sessions, during acquisition training with the dynamic stimuli (flashing/steady green); both subjects were trained with the same/different procedure. Neither Coco nor Roscoe met the acquisition criterion (90% correct in one session) in their allotted 52 and 40 sessions, respectively. Twenty-eight sessions of training with compound samples were interposed between Coco's 26th and 27th training sessions (see text).

pond sample stimulus was composed of the red disk with superimposed vertical and horizontal lines (referred to as red•plus), and the other was the red disk with superimposed circle and dot (red•circle•dot). The incorrect comparison stimulus used with the first sample was either red•vertical line or red•horizontal line; it was either red•circle or red•dot in the case of the second sample.

To be correct in this more challenging matching task, the subject had to ignore the common components present in both the incorrect comparison stimulus and the sample. We thought that the monkeys' difficulty with the dynamic stimuli might be due in part to the fact that they shared identical components. During the on time of the flashing green disk, for example, it was essentially identical to the steady green disk. Moreover, virtually all of the experienced monkeys' past matching training was with incorrect comparison stimuli that had no components in common with the sample stimulus. Training the subjects to ignore such common elements might therefore facilitate performance with the dynamic stimuli.

Olive averaged 86.3% correct responses over the last two sessions with the compound samples. Nevertheless, when returned to the dynamic stimuli on Session 33, her matching performance showed no immediate improvement over previous levels (Figure 4).

After the 26th acquisition session with the dynamic stimuli, Coco was given 28 40-trial sessions of training with several different compound samples, including those presented to Olive. Her best two-session average, which was reached near the end of training, was 77.5% correct. Figure 5 reveals that, as with Olive, the compound sample training did not immediately profit Coco, nor did it allow Coco to reach criterion during the additional 26 training sessions.

Surprisingly, analysis of Olive's responses over the last 10 acquisition sessions with the dynamic stimuli revealed a lower percentage of correct responses when steady green was the sample than when flashing green served this role: 49.2% correct versus 79.2%. Given Olive's previously demonstrated competence to match a steady red sample, one would have expected the opposite result. The explanation seems to be that during the course of training this subject developed a consistent and rather strong preference for responding to the flashing green comparison stimulus. In each of the last 10 sessions she responded more to flashing green than to steady green, with an overall disparity of 65% to 35%.

The responses of Coco and Roscoe during their final 10 training sessions were analyzed in terms of three stimulus configurations, steady green same trials, flashing green same trials, and different trials. Again, in view of these subjects' previous experience with same red trials (Table 1), one might expect a relatively high performance level with the corresponding steady green trials. Not so. Coco averaged only 40.0% correct on these trials but 70.8% correct on same flashing green trials; she scored 75.0% correct on the different trials. This pattern of results suggests an attempt to treat the task as a discriminative problem: Press the right (different) lever if at least one steady green disk appears, otherwise respond to the left (same) lever. If Coco adopted such a strategy on 40% of the trials, responding on a chance basis on the remaining 60%, the expected percentages of correct responses for the three stimulus configurations are 30, 70, and 70, respectively, reasonably similar to the obtained values. Roscoe scored 38.3%, 42.4%, and 63.8% correct responses on same steady, same flashing, and different trials, a pattern consistent with a general bias to press the right (different) lever.

*Discriminability test.* Two control monkeys



in the D'Amato et al. (1985) study were trained to discriminate the flashing and steady green disks to a criterion of at least 90% correct responses in two consecutive sessions. They acquired the task in only four to six sessions, indicating that the dynamic stimuli were easily discriminable. To verify this result for the present subjects, after their 52nd matching session, Olive and Coco were given 48-trial discrimination training sessions with the flashing and steady green disks. For both subjects, completion of the FR 4 on the microswitch presented the two dynamic stimuli on any two of the outer four projectors. Pressing the key on which the positive stimulus appeared produced the usual reinforcement, whereas responding to the negative stimulus resulted in the customary timeout.

Because of Olive's preference for responding to the flashing comparison stimulus—which is itself evidence of discriminative behavior—steady green was assigned as the positive stimulus. The nature of the S/D task precluded determining a comparable preference for Coco; consequently, flashing green was designated as her positive stimulus. Training was continued until at least 90% correct responses were made in a single session.

Figure 6 shows that after overcoming her preference for flashing green, which took three sessions, Olive quickly satisfied the designated criterion. Coco, who did not show a preference in the first session, met the acquisition criterion in the very next session. The rapidity with which the 2 subjects learned the discrimination is rendered more notable by the fact that they had just completed an extended period of attempting to cope with these identical stimuli within the same general context but in a paradigm that imposed quite different response requirements.

## DISCUSSION

In contrast to results reported for pigeons (Edwards et al., 1983), monkeys are clearly capable of S/D learning when all configurations of the sample set are used (see Burdyn & Thomas, 1984; King & Fobes, 1975). And after S/D training with a small number of static visual stimuli, monkeys' S/D behavior can generalize to new static stimuli. Perhaps more significant, Jane, who previously had learned to match flashing and steady green

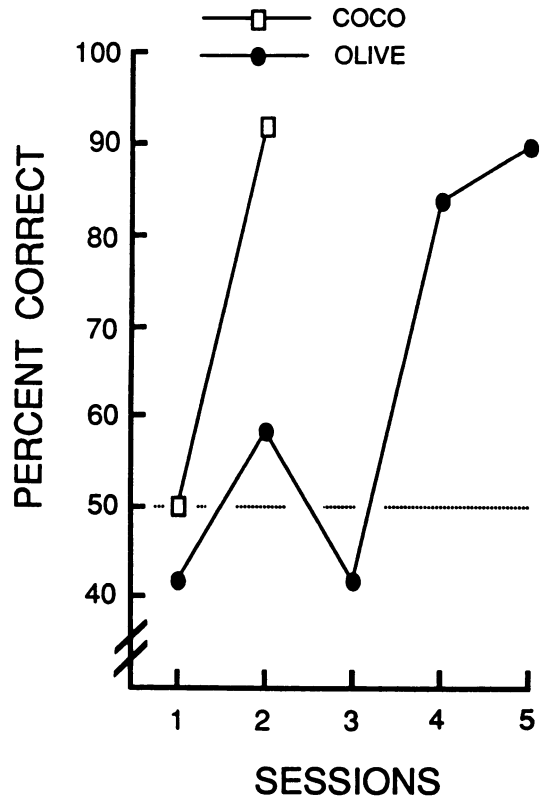


Fig. 6. Percentages of correct responses during the 48-trial discrimination sessions with the dynamic stimuli that followed same/different acquisition training (Figures 4 and 5). Coco met the criterion (90% correct in one session) on Session 2; Olive, trained against the preference that she earlier displayed for responding to flashing green, required five sessions.

within a standard matching-to-sample paradigm, showed virtually immediate transfer to these stimuli when tested with the S/D procedure. These findings indicate that, in monkeys at least, the matching and S/D paradigms reflect essentially the same competence.

On the other hand, there are features of the monkeys' behavior during S/D learning that appear inconsistent with the interpretation that their performance was governed by judgments of sameness. For example, it is difficult to understand why Roscoe and Jane required so much training to progress from the successive to the simultaneous S/D procedure (Table 1). The only difference between the two was that in the former a response to the stimulus that appeared on the lower right projector was required to obtain the other stimulus member of

the pair (on the lower left projector) and to enable the levers; in the latter procedure no such response was required, all of the relevant stimuli being presented simultaneously.

It could be argued that throughout successive S/D training Roscoe and Jane maintained essentially a matching procedure mode, treating the stimulus on the lower right projector as a sample stimulus. Presenting both members of a pair simultaneously might be expected to disrupt this strategy. As a matter of fact, the subjects were often observed to respond to the lower right projector during the simultaneous training phase. However, during the later sessions such responses were infrequent and, with one exception, little difficulty was encountered with sample sets other than the first. It therefore seems reasonable to assume that by the end of the simultaneous S/D training phase the behavior of both monkeys was governed by sameness judgments rather than by old/new or familiar/unfamiliar comparisons. If her performance is any guide, Coco adopted the former strategy very early in the successive S/D training phase.

But if this account is correct, why did Roscoe and Jane, with the highly familiar circle and vertical line serving as the sample set, again experience difficulty when advanced to the five-key S/D phase? The answer may lie in the suggestion of Iversen, Sidman, and Carrigan (1986) that spatial location can play a role in the defining characteristics of discriminative stimuli. The matching performance of rhesus monkeys accustomed to having sample stimuli (horizontal/vertical lines) appear on the center of three, linearly arranged, projectors was seriously impaired when the samples were presented on the side keys. Apparently, when discriminative stimuli consistently appear in the same locations, animals may come under the control of configural aspects of the stimuli or, anticipating the appearance of the stimuli in certain locations, they may be able to perform efficiently while attending only to limited features of the stimuli. The high performance levels achieved by Coco and Jane in five-key training with the five-sample set (Figure 1) indicate that if stimulus location had been a controlling cue for these subjects, its effect was largely dissipated by the end of this phase. The same may not have been true for Roscoe, whose performance became more stable by restricting the stimuli to the lower projectors.

It seems reasonable to conclude, therefore,

that by the end of five-key S/D training, Coco and Jane, and most likely Roscoe as well, based their evaluations of the discriminative stimuli on sameness/difference and not on old/new or familiar/unfamiliar. Indeed, Jane's immediate transfer to the dynamic test stimuli and the transfer results of the other subjects (discussed below) suggest to us that sameness/difference judgments were not acquired in the S/D training but rather formed the basis of the monkeys' matching behavior in our standard matching-to-sample paradigm. Additional support for this interpretation comes from the fact that, whereas some 28,000 training trials were required by Sands and Wright's (1980) experimentally naive rhesus monkey to master their two-projector S/D task, our monkeys completed simultaneous S/D training in only 900 to 2,600 trials (Table 1), suggesting substantial positive transfer from their previous matching experience.

Turning to the major results of the present experiment, Olive's massive experience matching a wide variety of static visual stimuli did nothing to facilitate transfer to flashing and steady green. Indeed, despite 52 training sessions she failed to learn to match these stimuli, suggesting that her earlier experience with static visual stimuli, instead of promoting transfer to dynamic stimuli, might have been a source of interference. As already noted, the four monkeys of the D'Amato et al. (1985) study, who had only limited experience matching static visual stimuli, all learned in 44 or fewer sessions to match flashing and steady green disks to a strict accuracy criterion.

Coco and Roscoe, trained and tested with the S/D procedure, also failed to transfer to the dynamic stimuli or to acquire the task within 52 and 40 sessions, respectively. The acquisition deficiency provides additional evidence that extensive experience matching static stimuli may result in negative transfer to dynamic stimuli. Of greater significance, the failure to transfer offers no support for our conjecture that the S/D procedure would so increase the abstractness of the monkeys' identity concept that it would extend to dynamic stimuli. On the other hand, it provides further evidence that the matching-to-sample and S/D paradigms tap the same competencies, at least in monkeys.

It should be emphasized that the failure of the 3 subjects to transfer to the dynamic stimuli, or even to learn to match them despite

extended training, cannot be attributed to difficulty in discriminating the steady from the flashing green disk. The maximum performance level managed by Olive in her 52 sessions of matching the dynamic stimuli was only 73% correct; yet, even though trained against a strong bias to respond to flashing green, she met the 90% correct discrimination criterion in five sessions. Remarkably, Coco, whose maximum performance in her 52 training sessions was 77% correct, reached the 90% discrimination criterion in a mere two sessions. Clearly, the problem was not in differentiating the dynamic stimuli but rather in applying the matching (or S/D) rule to them.

We conclude from the present results that in both the matching and the S/D paradigms monkeys normally base their instrumental behavior on sameness/difference judgments. However, such judgments do not appear to be very abstract. Tethered by the context in which they are acquired, they can stretch to novel stimuli within the same general class of stimuli that brought them into being, but not very far beyond. Failures of the matching concept to transfer from one sensory modality to another are well documented (e.g., D'Amato & Colombo, 1985; Milner, 1973; Salmon, 1984), and the present results, in conjunction with our earlier findings (D'Amato et al., 1985), suggest that a similar limitation applies to the visual modality itself, at least insofar as static and dynamic stimuli are concerned.

As pointed out earlier (D'Amato et al., 1985), if our monkeys' failure to transfer from static to dynamic stimuli is due simply to the separateness of the two classes of stimuli, then the failure to transfer should be symmetric. On the other hand, if matching dynamic stimuli is somehow a more abstract endeavor than matching static stimuli (despite the readiness with which monkeys discriminate steady from flashing stimuli), transfer to static stimuli might very well be observed. But even in this case, the failure to transfer from static to dynamic stimuli represents a serious limitation with regard to the scope of the monkey's matching concept. We had planned to evaluate transfer from dynamic to static visual stimuli, but due to the lack of acceptable quarantine facilities to house the required additional subjects, this proved impossible.

We have pointed out that with sufficient additional appropriate training the matching concept can be extended from static to dynamic

visual stimuli and from one sensory modality to another. Would an animal thus tutored have a generalized matching concept rivaling that of a language-trained chimpanzee or a young child? As an example, Tiny, who served in the D'Amato et al. (1985) study, displayed concept-mediated transfer to static visual stimuli after experience with only two exemplars; he failed to transfer to flashing/steady green but showed concept-mediated transfer to dynamic visual stimuli after experience with four additional dynamic exemplars. He subsequently did not transfer matching to the auditory modality but acquired the matching task with dispatch and then transferred to novel acoustic cues at a level that indicated the matching concept in the auditory modality (D'Amato & Colombo, 1985). Did Tiny's separate matching competencies somehow coalesce into a generalized matching concept capable of extending to totally new classes of stimuli? For the following reasons, we think it doubtful.

As a subject in the study by Colombo (1989), which examined the role of auditory association cortex in the monkey's memory for acoustic stimuli, Tiny received extensive training in closely comparable visual and auditory delayed-matching tasks (see Colombo & D'Amato, 1986). After unilateral auditory association cortex removal, visual and auditory retention remained intact. Following ablation of the contralateral auditory association cortex, visual memory was still completely normal. Surprisingly, however, Tiny's matching ability in the auditory modality was abolished. He could discriminate the familiar acoustic exemplars but he was unable to match them, even after extensive retraining efforts.

This astonishing dissociation, which was obtained in another monkey, suggests that the structural mechanisms that mediate same/different judgments in the monkey are modality specific, and that such mechanisms do not funnel into a common center that might serve as a generalized same/different processor. Indeed, recent developments in the structural basis of primate vision indicate a surprising degree of segregation of function within the visual modality itself. Very briefly and much simplified, Livingstone and Hubel (1988) have described a "parvo" system that plays a central role in detailed processing of color, shape, and surface properties of objects; the temporal resolution of the parvo system is, however, low. A structurally distinct "magno" system spe-

cializes in processing movement, contrast, and depth; its temporal resolution is high. As the two systems are structurally segregated even at higher cortical levels, the intriguing possibility presents itself that matching of static stimuli is primarily the province of the parvo system whereas matching dynamic stimuli is mediated mainly by the magno system.

If there is any substance to this hypothesis, it would nicely account for the failure to transfer from static to dynamic stimuli, and it would provide a common structural interpretation of intermodal and intramodal failures to transfer same/different judgments. It also has clear behavioral implications. Monkeys should not transfer matching from dynamic to static stimuli, and transfer from stationary static stimuli to static stimuli that move in space at different rates should also prove difficult.

Although it remains to be seen whether these predictions will be confirmed, we are persuaded by the currently available data that it is unlikely that a generalized matching concept can be assembled in the monkey, or in most other animals, simply by piecemeal aggregation. The capacity to construct symbolic representations of same and different, as found in children or in language-trained chimpanzees (Premack, 1983b), may prove a necessary prerequisite for an abstract matching concept.

## REFERENCES

- Bower, T. G. R. (1974). *Development in infancy*. San Francisco: Freeman.
- Burdyn, L. E., Jr., & Thomas, R. K. (1984). Conditional discrimination with conceptual simultaneous and successive cues in the squirrel monkey (*Saimiri sciureus*). *Journal of Comparative Psychology*, **98**, 405-413.
- Caron, A. J., & Caron, R. F. (1982). Cognitive development in early infancy. In T. M. Field, A. Huston, H. C. Quay, L. Troll, & G. E. Finley (Eds.), *Review of human development* (pp. 107-147). New York: Wiley.
- Colombo, M. W. (1989). *The role of the auditory association cortex in the processing and retention of acoustic information in monkeys (Cebus apella)*. Unpublished doctoral dissertation, Rutgers—The State University, New Brunswick, NJ.
- Colombo, M., & D'Amato, M. R. (1986). A comparison of visual and auditory short-term memory in monkeys (*Cebus apella*). *Quarterly Journal of Experimental Psychology*, **38B**, 425-448.
- Cox, J. K., & D'Amato, M. R. (1982). Matching to compound samples by monkeys (*Cebus apella*): Shared attention or generalization decrement? *Journal of Experimental Psychology: Animal Behavior Processes*, **8**, 209-225.
- Czerny, P., & Thomas, R. K. (1975). Sameness-difference judgments in *Saimiri sciureus* based on volumetric cues. *Animal Learning & Behavior*, **3**, 375-379.
- D'Amato, M. R., & Colombo, M. (1985). Auditory matching-to-sample in monkeys (*Cebus apella*). *Animal Learning & Behavior*, **13**, 375-382.
- D'Amato, M. R., Salmon, D. P., & Colombo, M. (1985). Extent and limits of the matching concept in monkeys (*Cebus apella*). *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 35-51.
- Edwards, C. A., Jagielo, J. A., & Zentall, T. R. (1983). "Same/different" symbol use by pigeons. *Animal Learning & Behavior*, **11**, 349-355.
- Iversen, I. H., Sidman, M., & Carrigan, P. (1986). Stimulus definition in conditional discriminations. *Journal of the Experimental Analysis of Behavior*, **45**, 297-304.
- King, J. E., & Fobes, J. L. (1975). Hypothesis analysis of sameness-difference learning-set by capuchin monkeys. *Learning and Motivation*, **6**, 101-113.
- Livingstone, M., & Hubel, D. (1988). Segregation of form, color, movement, and depth: Anatomy, physiology, and perception. *Science*, **240**, 740-749.
- Milner, A. D. (1973). Matching within and between sense modalities in the monkey (*Macaca mulatta*). *Journal of Comparative and Physiological Psychology*, **83**, 278-284.
- Nissen, H. W. (1953). Sensory patterning versus central organization. *Journal of Psychology*, **36**, 271-287.
- Nissen, H. W., Blum, J. S., & Blum, R. A. (1948). Analysis of matching behavior in chimpanzee. *Journal of Comparative and Physiological Psychology*, **41**, 62-74.
- Premack, D. (1983a). Animal cognition. *Annual Review of Psychology*, **34**, 351-362.
- Premack, D. (1983b). The codes of man and beasts. *Behavioral and Brain Sciences*, **6**, 125-137.
- Robinson, J. S. (1955). The sameness-difference discrimination problem in chimpanzee. *Journal of Comparative and Physiological Psychology*, **48**, 195-197.
- Salmon, D. P. (1984). An investigation of modality specificity in the cognitive processes of monkeys (*Cebus apella*) (Doctoral dissertation, Rutgers—The State University). *Dissertation Abstracts International*, **45**, 706B.
- Sands, S. F., & Wright, A. A. (1980). Serial probe recognition performance by a rhesus monkey and a human with 10- and 20-item lists. *Journal of Experimental Psychology: Animal Behavior Processes*, **6**, 386-396.
- Santiago, H. C., & Wright, A. A. (1984). Pigeon memory: Same/different concept learning, serial probe recognition acquisition, and probe delay effects on the serial-position function. *Journal of Experimental Psychology: Animal Behavior Processes*, **10**, 498-512.
- Weinstein, B. (1941). Matching-from-sample by rhesus monkeys and by children. *Journal of Comparative Psychology*, **31**, 195-213.
- Wilson, B., Mackintosh, N. J., & Boakes, R. A. (1985a). Matching and oddity learning in the pigeon: Transfer effects and the absence of relational learning. *Quarterly Journal of Experimental Psychology*, **37B**, 295-311.
- Wilson, B., Mackintosh, N. J., & Boakes, R. A. (1985b). Transfer of relational rules in matching and oddity learning by pigeons and corvids. *Quarterly Journal of Experimental Psychology*, **37B**, 313-332.

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