JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1979, 31, 259-266 NUMBER 2 (MARCH)

MATCHING-TO-SAMPLE AND ODDITY-FROM-SAMPLE IN GOLDFISH[1]

MARJORIE GOLDMAN AND SANDRA SHAPIRO

QUEENS COLLEGE OF THE CITY UNIVERSITY OF NEW YORK

Acquisition of three-alternative simultaneous matching-to-sample and oddity-from-sample was investigated. Five goldfish were trained on matching and five on oddity for a minimum of 70 days. Subsequently, six of the fish were trained for 70 days on the other task. Acquisition was similar for oddity and matching. Correct responding started at about chance level and slowly increased to about 75%, with some animals performing at levels of over 85%. Acquisition of oddity following matching and matching following oddity began below chance. Maximal level of performance on second-task oddity was comparable to that on first-task matching. By contrast, the maximal levels of performance when matching was the second task were not as high as that of the same subjects at the end of first-task oddity. All fish exhibited strong color preferences during matching acquisition but not during oddity acquisition. The data demonstrated that goldfish can acquire a discrimination in which the stimulus associated with reinforcement depends on the identity of a second stimulus.

Key words: matching-to-sample, oddity-from-sample, transfer, mouth-key press, goldfish

The study of complex discrimination processes in lower mammals and in nonmammalian species is of interest in view of the debate as to whether phyletically diverse species may be ordered with respect to behavioral differences (Bitterman, 1965, 1969, 1975; Hodos & Campbell, 1969; Mackintosh, 1969). Bitterman (1965) attempted to form a behavioral taxonomic scale based on performance differences among several animal species on various tasks. It would seem that whether some form of scaling is useful (Bitterman, 1965) or not (Hodos & Campbell, 1969) should be determined by the pattern of behavioral similarities and differences obtained in a program of comparative study of such long divergent groups as teleost fish, birds, and mammals.

It is well known that goldfish (*Carassius auratus*) can master simultaneous and successive discrimination problems (Gleitman & Rozin, 1971), and recently it has been shown that performances improve during a series of discrimination reversals (Engelhardt, Woodward, & Bitterman, 1973). Zuckerman and Blough (1974) demonstrated that goldfish could acquire a conditional discrimination in which responses to one particular combination of light and sound intensity were reinforced and responses to all other intensity combinations, some of which included one of the stimuli present in the reinforced compound, were not reinforced. The fish responded more often to the reinforced compound, and generalization gradients showed that the fish attended to both stimulus dimensions. It has not yet been demonstrated that fish can solve conditional discrimination problems in which the stimulus associated with reinforcement on each trial depends on a second stimulus which also differs from trial to trial, as in the case of matching-to-sample and oddity-from-sample (hereafter called matching and oddity).

The results of a systematic investigation of matching and oddity (Cumming & Berryman, 1965), using pigeons as subjects, did not confirm Skinner's (1950) prediction that, since logically the two problems appear to be opposites, it should be no more difficult to acquire a response to the stimulus which is the same as the sample than to acquire one to the stimulus different from the sample. Cumming and Berryman used three different colors as stimuli (three-alternative), but only two were pre-

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[1] This report is based on a dissertation submitted by Marjorie Goldman to the Graduate School of the City University of New York in partial fulfillment of the requirements for the PhD degree. Portions of these data were presented by Marjorie Goldman at the Eastern Psychological Association meetings, New York City, April 1976. This research was supported in part by grant FRAP 1721 to Sandra Shapiro from the Faculty Research Program of the City University of New York. Reprints may be obtained from Sandra Shapiro, Department of Psychology, Queens College, Flushing, New York 11367.

sented on each trial. On a three-key display, the center and one of the side keys were the same color while the remaining side key was one of the two other colors. In the matching problem, the bird was reinforced for pecking at the side key of the same color as the center sample, and for oddity the bird was reinforced for pecking at the different color. These procedures are examples of conditional discriminations in which the center sample stimulus determines which discrimination is appropriate.

A primary concern in the analysis of conditional discriminations is the nature of the stimuli controlling the response. Cumming and Berryman (1965) found that matching performances began at chance level and were accompanied by strong position preferences. When position biases diminished, small color biases were observed. As preferences decreased, correct responding quickly reached levels well above 90%. By comparison, oddity performances began above the chance level, indicating a preference for the odd stimulus, and rose more gradually to a maximum of about 90%. During oddity learning, there were much lower position preferences, and color preferences fluctuated unsystematically (Berryman, Cumming, Cohen, & Johnson, 1965). Changes in these preferences were not reflected in the acquisition functions. Cumming and Berryman (1965) hyopthesized that a maintained position preference was an aid to matching acquisition and therefore to the more accurate performance by the matching animals.

The present study investigated acquisition of matching and oddity in goldfish. The operant conditioning techniques of Cumming and Berryman (1965) were used in a standard discrimination chamber developed for fish by Longo and Bitterman (1959). To better understand the fish's performances and to compare these data to those from pigeons, a detailed analysis of the stimuli controlling the behavior of the fish was attempted. In addition, some of the fish in the present experiment were trained on both tasks in succession, thus permitting within-subject comparisons between acquisition of matching and oddity.

METHOD

Subjects

Ten experimentally naive goldfish, 7 to 13 cm in length from tip of the nose to base of the tail, were purchased from a local pet store. They were housed individually in 9.5-liter tanks (length 31 cm, width 16.5 cm, height 20.5 cm) continuously aerated through plastic filters. The room temperature was maintained at about 21° C. Fluorescent room lights were kept on continuously.

Apparatus

The subjects were tested individually in a three-key chamber modified after that of Longo and Bitterman (1959). The fish's home tank, with filter removed and debris siphoned, was placed in a black Plexiglas testing chamber that had a hinged side door and top lid. The side door opened along the 31-cm side of the tank and the lid was lowered into the tank in front of the 16.5-cm end. Attached to the lid were three steel rods; a clear Plexiglas disc, 3 cm in diameter, was attached to the end of each rod, with a space of 1 cm between discs. The rods were suspended from crystal phonocartridges (Turner Model A and Astatic Model 12U) that converted a mechanical displacement into an electrical signal. The analog output from the cartridges was converted to a digital signal. The differences in the phonocartridge outputs were compensated for by adjusting the sensitivity of all three channels of the converter. The gain of the analog sections of the converters was observed on an oscilloscope and adjusted while 10 g of pressure was applied to each disc. A channel setting for the three discs was determined empirically in the water for each fish. A sheet of metal, painted black, extending 8.5 cm below the lid kept the fish from contacting the rods, and thus ensured that the recorded responses were those made to the disc. Four black metal strips separated the discs and prevented the fish from hitting more than one disc at a time.

With the lid lowered, the transparent discs were in a row exactly in front of three transparent windows. Behind the windows, mounted on the wall outside the testing chamber, were three stimulus projectors (Grason Stadler #E4580-156). The stimuli used for both matching and oddity were white, red (Wratten filter #25A), green (Wratten filter #61), and blue (Wratten filter #47) lights. A translucent white Plexiglas panel, behind which two lightbulbs were mounted, was at the end of the testing chamber opposite the discs. These lights were turned on after a correct response. Food (brine shrimp) reinforcement was delivered through a hole in the lid 5 cm from the lighted end of the tank. A bank of eye droppers, arranged on a rotating platform above the box, held the brine shrimp, and a dropper was squeezed by a solenoid-actuated clamp to deliver a single shrimp.

All phases of the stimulus presentation and response recording were programmed using electromechanical equipment located in the same room as the testing chamber. With the exception of the brine shrimp platform, operation of the equipment did not cause vibrations in the fish's water.

Procedure

Pretraining. Following magazine training during which brine shrimp were presented in the presence of the reinforcement light, the center disc was transilluminated with white light and the response of pressing the center disc with the mouth was shaped. When the fish consistently pressed the disc within about 2 sec of its illumination, center disc responses were followed by the transillumination of both side discs with white light. Responses to either illuminated side disc were then reinforced until side disc responding was rapid and reliable (averaging 300 to 500 trials over a two-day period). Since responses were made to both side discs, no attempt was made to control the number or order of responses to the two sides. An intermittent reinforcement schedule was in effect during pretraining because about 10% of the reinforcers remained in the dropper or missed the hole. The fish were given their maintenance diet (shrimp pellets) immediately after pretraining sessions with the exception that fish which did not respond were not fed.

Conditional discrimination training. Two procedures were used: three-alternative simultaneous matching and three-alternative simultaneous oddity. When a red, green, or blue light (sample) appeared behind the center disc, a single press on the center disc resulted in the immediate appearance of stimuli behind the two side discs (the center stimulus remained on). One side stimulus was the same color as the sample, and the other side stimulus was one of the two remaining different colors. In the matching problem, the side stimulus which was the same as the center sample was designated correct. In the oddity problem, the side stimulus which was different from the center color was designated correct. There are 12 possible combinations of the three colors, given the restriction that one side must be the same color as the center. A pseudorandom order was determined for these 12 stimulus combinations and then repeated in reverse to provide a sequence of 24 trials. This sequence was repeated five times per session, 120 trials in all. A noncorrection procedure was employed, i.e., incorrect trials were not repeated.

A correct response turned off all key lights and was followed by the reinforcement light for 10 sec. Delivery of the reinforcer, a brine shrimp, was on a random reinforcement schedule of either 30% or 90%. On the first day of discrimination training, the 90% reinforcement schedule was in effect for all animals. Three of the animals, 4, 21, and 32, remained on the 90% schedule until Day 35 of training, while the other seven were trained on the 30% schedule beginning on Day 2. An incorrect response turned off all key lights and was followed by a 10-sec blackout, which ended the trial. Following both correct and incorrect trials, there was a 4-sec intertrial interval in darkness, after which the center disc was illuminated for the next trial. Additional responses to the center or side discs were not counted and had no consequences. There was no time limit for responding; the center and/or side discs remained illuminated until a response was made. The fish were fed food pellets immediately after they completed a session. In rare instances, when a response did not occur for an hour or more, the fish was removed from the apparatus and not fed. Training sessions were conducted daily.

Five fish were trained on the oddity problem and five on the matching problem. After 70 days of training, three members of each group were shifted to the other task, and training was continued for another 70 days. The fourth member of each group continued on the original task for more than 70 days. The remaining two fish became sick after completion of 70 days of training on the initial task and were not continued in the experiment.

RESULTS AND DISCUSSION

Figure 1 summarizes performances of the five fish trained initially on the matching problem in terms of percentage of correct re-

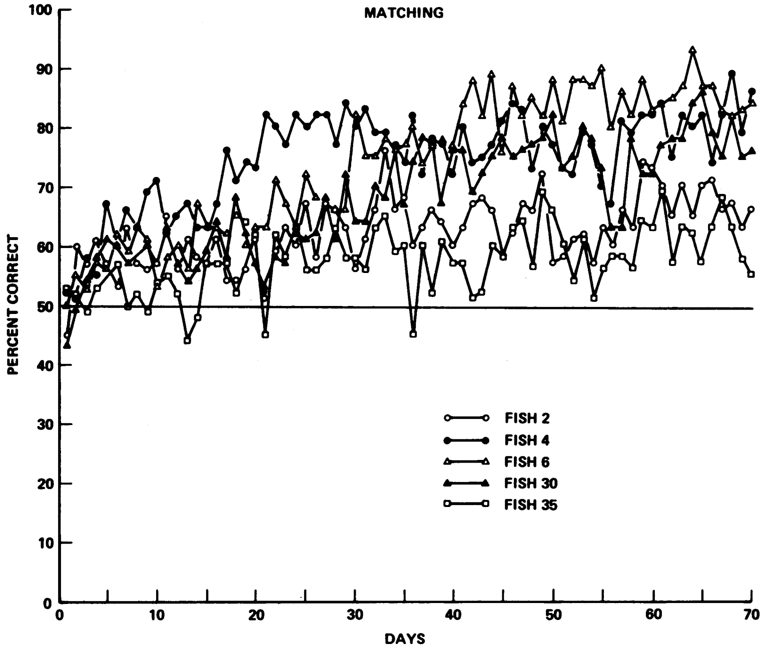

Fig. 1. Percentage of correct responses as a function of days for first-task matching-to-sample acquisition.

sponses on each day. Similar data for the fish trained on the oddity problem are given in Figure 2. Although there was substantial variation from fish to fish in rates of acquisition and terminal performance levels, the figures do not indicate systematic differences in the acquisition curves for matching and oddity. For both tasks, acquisition started at about the chance (50%) level and increased slowly to a maximal level, averaging across subjects,

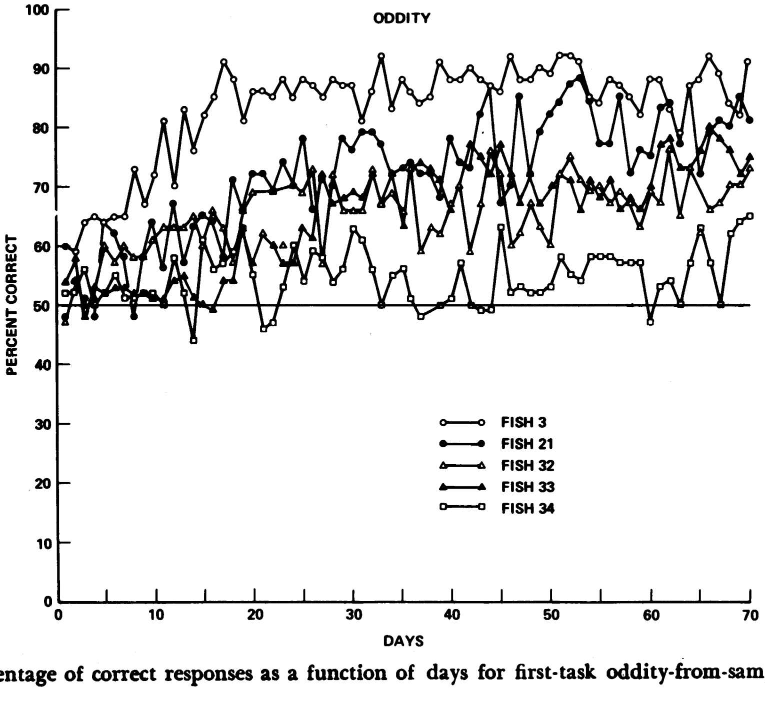

Fig. 2. Percentage of correct responses as a function of days for first-task oddity-from-sample acquisition.

of about 75% at the end of 70 training days. Terminal performance levels showed similar variations in the matching and oddity groups, ranging from about 60% (Fish 35) to about 85% (Fish 6) for the matching problem, and from 57% (Fish 34) to 88% (Fish 3) for the oddity problem. Comparable individual differences in speed of acquisition can be seen to occur in each group.

There was some evidence that an asymptotic level of performance may not have been reached after 70 days of training. Fish 2, trained on matching, performed at a level of 67% after 70 training days but reached an 85% correct level after 110 days. Only slight increases (to 92%) were shown during the further oddity training of Fish 3, which had already reached the 86% level by day 20.

These results demonstrate that goldfish can acquire discriminations based on matching-to-sample and oddity-from-sample configurations. Comparison of these data with data available from pigeons (Cumming and Berryman, 1965) show differences in patterns of acquisition between species. In terms of absolute levels of performance, the majority of goldfish reached a 75% level by the end of 70 training days, whereas pigeons reached accuracies of 90% or better after 20 days of training. Goldfish acquired both matching and oddity at a slow rate with gradual increases in correct responding. Pigeons also showed gradual increases in correct responding during oddity training, but matching acquisition was characterized by rapid increases in correct responding after an initial period of chance responding. Initial level of performance was at or around chance for goldfish on either task and for pigeons learning matching, but pigeons showed an initial preference for the odd stimulus during oddity learning and thus started at an above-chance level. This preference for the odd stimulus by pigeons may not reflect a true species difference but rather a difference in the shaping procedures used for pigeons and fish. Pigeons, such as those of Cumming and Berryman (1965), have usually been shaped to peck at the center key lit with one color and subsequently given equal numbers of reinforcements for response to each of the colors on each of the three keys, while the two other keys were simultaneously present but unlighted. This procedure may have biased the pigeons toward an oddity preference and/or against a matching preference. By contrast, in the present study, the final shaping procedure required a response to a center white light, which resulted in the illumination of two side white lights, response to either of which was reinforced, thus biasing performance in favor of matching.

Figure 3 shows acquisition curves for the

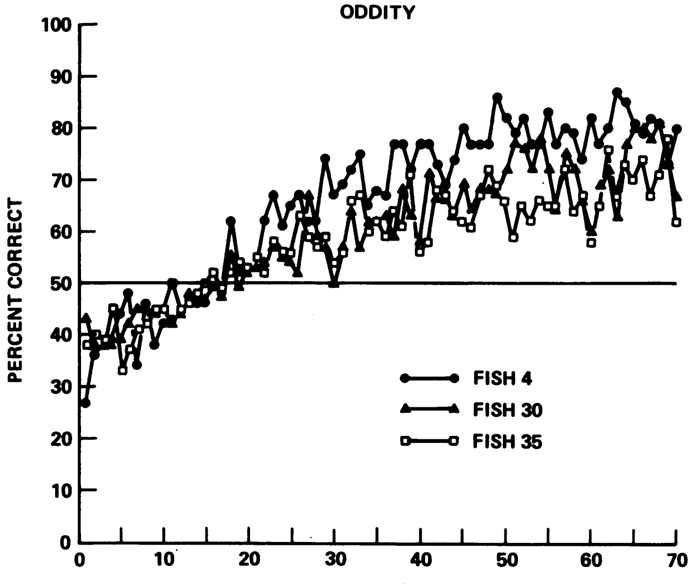

Fig. 3. Percentage of correct responses as a function of days for oddity-from-sample acquisition following 70 days of matching-to-sample training.

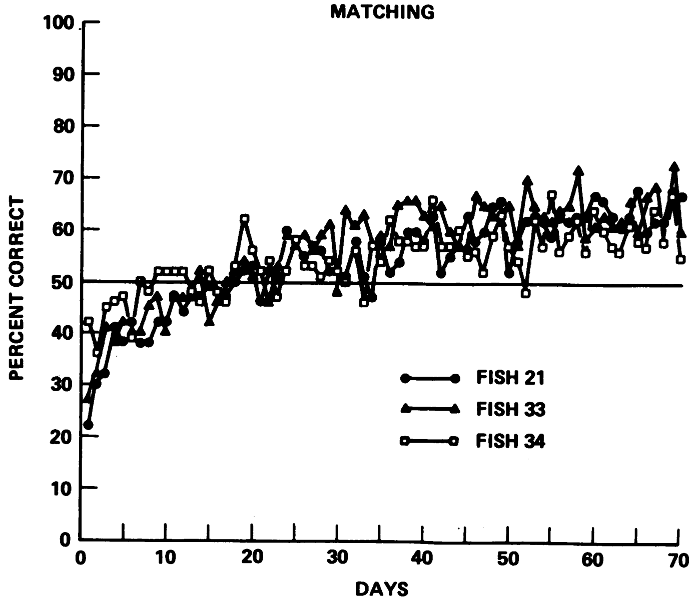

Fig. 4. Percentage of correct responses as a function of days for matching-to-sample acquistion following 70 days of oddity-from-sample training.

three fish trained on the oddity problem after 70 days of matching training, and Figure 4 shows the acquisition curves for the three fish trained on the matching problem after 70 days of oddity training. Second-task acquisition was similar to first-task acquisition in that it was characterized by a slow and steady increase in percentage of correct responses, thus replicating the previous results. In all fish, the percentage of correct responses for the initial days was depressed below the chance level, suggesting negative transfer from the first task. On the first day of second-task training, the fish tended to respond as though they were still on first-task training. This negative transfer effect confirmed that first-task acquisition was associated with the conditional discrimination task rather than any uncontrolled extraneous variables.

The individual acquisition curves within each group showed greater overlap on the second task, possibly reflecting the influence of the common experience of extended discrimination training. As can be seen in Figures 3 and 4, the fish trained on oddity showed greater improvement than those trained on matching. All three fish trained on oddity reached the same level of accuracy at the end of 70 days that they had attained on matching during first-task training. On the other hand, two of the three fish trained on second-task matching were at lower levels at the end of 70 days than they had achieved on first-task oddity. (The third fish had scores of about 60% at the end of both tasks.) Thus, the history of training with the alternative task retarded initial acquisition, and possibly, in the case of matching, resulted in lowered terminal levels of performance.

Response biases were then examined to determine whether, despite the similarity in acquisition, more subtle differences between matching and oddity performances might be detected. For each fish it was determined whether any of twenty-six biases toward a particular color, side, or side-color combination were present on each day of training. The color preference score indicated the proportion of daily trials on which responses to the stimulus colors differed from chance. Each color appeared on either side disc on a total of 80 trials, 40 times as the correct alternative and 40 times as incorrect. If an animal had no color bias (e.g., performing perfectly or randomly), it would respond to each color 40 times. The color preference score was calculated by adding the absolute value of the deviations from 40 (chance responding) for each color and dividing this sum by 80 (the total number of times any given color could be chosen). This score ranges from 0, no color preference, to 100%, complete color preference.

Figure 5 shows the color preference data for the six fish trained on both oddity and matching, with the first task in the left-hand column and the second task in the right. It is evident that color preferences were more prevalent during acquisition of matching than oddity, regardless of whether matching was the first or second task, and that color preference scores were much lower during acquisition of oddity. This tendency for color preferences to accompany matching acquisition but not oddity acquisition was evident in the records of the remaining fish. There was no consistent relation between the extent of the color preference and overall accuracy. For example, Fish 4 had a large color preference during initial matching acquisition, which was greatly reduced as performance improved; whereas Fish 30, whose acquisition was slower, showed fluctuating color preferences throughout training.

Position preferences were analyzed in a manner analogous to color preferences. Although

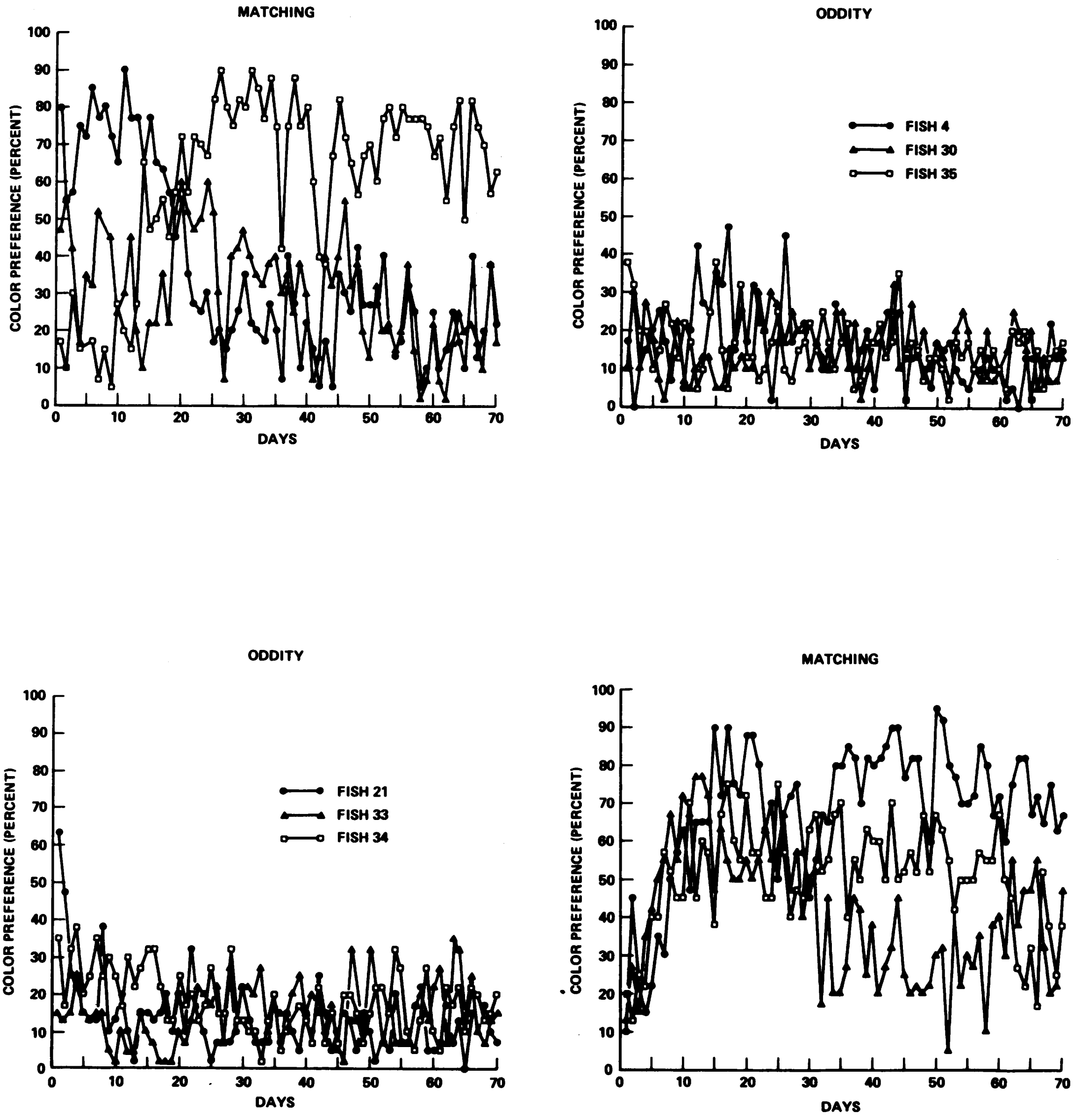

Fig. 5. Color preferences as a function of days for the six fish trained on both matching and oddity. Color preferences from the first task are on the left and those from the second task are on the right.

the fish varied in the extent of such preferences, they did not seem to be systematically related to the type of task. No consistent color or position preferences were shown by pigeons during oddity acquisition (Berryman et al., 1965). In the acquisition of matching, pigeons showed initial position preferences, followed by an increase in color preferences as the position biases decreased. The common finding, then, was that in both species systematic biases appeared during matching acquisition but not oddity. It remains to be determined which aspects of the reinforcement contingencies during matching training are responsible for these biases.

It had been proposed (Cumming & Berryman, 1965) that the presence of position preferences during matching training may have facilitated acquisition of that problem in pigeons. There was, however, no evidence in the present study that the presence of color preferences facilitated matching acquisition. Although all animals learning matching showed a color preference, the acquisition curves when matching was the initial task were not distinguishable from those for oddity, and the acquisition curves when oddity was the second task showed higher final levels than matching.

Finally, the effects of varying the level of intermittent primary reinforcement (accompanied by continuous secondary reinforcement) during the training period were examined. Differences in this regard were not apparent between the animals trained on the 90% reinforcement schedule (Fish 4, 21, and 32), and the remaining seven animals trained on the leaner, 30% reinforcement schedule.

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Received August 29, 1977
Final acceptance September 11, 1978