TRANSFER OF MATCHING-TO-SAMPLE IN PIGEONS[1]

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In Experiment I, pigeons were first trained on simultaneous matching-to-sample with either color stimuli or form stimuli, and then shifted to stimuli on the other dimension. Matching performance in the first session with stimuli on a given dimension was not affected by prior matching training with stimuli on the other dimension. However, in the first six color-matching sessions pooled, birds with prior form-matching training performed significantly better than birds without any prior matching training. In Experiment II, birds with experience matching both colors and forms in separate sessions were tested with novel stimulus configurations involving either novel stimuli or novel combinations of familiar colors and forms. Matching performance was not affected by novel stimulus configurations, except that performance dropped to a chance level or below when the standard stimulus was novel. In Experiments II, III, and IV, three of four tests did not show any effect of prior reinforcement of pecks at a novel stimulus, presented alone, on subsequent matching of that stimulus. The results were interpreted as indicating that matching performance in pigeons depends on the learning of stimulus-response chains involving the specific stimuli employed during training. An incidental observation in Experiments I and II was that there were typically more excess pecks at the standard stimulus during form-matching sessions than during color-matching sessions, which may be related to the fact that form matching is more difficult than color matching.

In the matching-to-sample problem, the subject receives a reinforcer for choosing the comparison stimulus that is identical to the standard stimulus. What is learned by pigeons in solving the matching-to-sample problem? There are at least three conceivable answers to this question. (1) Pigeons learn a generalized matching concept, which is independent of the specific set of stimuli employed during matching training. (2) Pigeons learn a set of stimulus-response chains based on the specific standard stimuli employed during matching training. For example, "peck red on the center key, then peck red on a side key," and "peck green on the center key, then peck green on a side key." (3) Pigeons learn a set of discriminations based on the specific stimulus configurations employed during matching training. A stimulus configuration is a specific set of stimuli and their specific spatial arrangement on the left, center (standard stimulus), and right response keys, respectively. For example, given the configuration red-red-green, pecking the left key is reinforced, but given the configuration green-red-red, pecking the right key is reinforced.

An attempt to choose among these three hypotheses calls for experiments employing a transfer-of-training paradigm. In this paradigm, the subject is first trained with one set of stimuli until matching performance is at a high level. At this point the stimuli and the stimulus configurations employed during this initial training can be said to be familiar. Following this initial matching training, the subject is presented with a novel matching problem. There are several ways in which novelty may be introduced into the transfer-test problem, depending on what aspect of the stimulus configuration is changed: (1) A novel standard stimulus may be presented, with a familiar incorrect comparison stimulus. (2) A novel incorrect comparison stimulus may be presented, with a familiar standard stimulus. (3) A completely novel stimulus set may be presented, in which both the standard stimulus and the incorrect comparison stimulus are novel. (4) A

novel stimulus configuration may be presented that includes standard and incorrect comparison stimuli which are both familiar from previous matching training, but which have not been presented together in a configuration.

Each of three hypotheses regarding what is learned during matching training results in a different prediction regarding the transfer of matching to the four different types of novel problems. If pigeons learn a generalized matching concept during their initial matching training, then matching should transfer successfully to each of the four types of novel problems. On the other hand, if pigeons learn a set of discriminations based on the specific stimulus configurations that appear during matching training, then matching performance would be disrupted by any change in the stimulus configuration during the transfer test. An intermediate prediction would be made by the stimulus-response chaining hypothesis. If pigeons learn a set of stimulus-response chains, then matching should transfer to any novel configuration where the standard stimulus is familiar, but matching should not transfer to any novel configuration where the standard is a novel stimulus.

Previous research (e.g., Cumming and Berryman, 1961; Cumming, Berryman, and Cohen, 1965) supports the stimulus-response chaining hypothesis. In these earlier experiments, matching was disrupted by novel configurations involving a novel standard stimulus and a familiar incorrect comparison stimulus, but not by novel configurations involving a familiar standard stimulus and a novel incorrect comparison stimulus. However, the stimulus-response chaining hypothesis cannot be regarded as proven, because the results of these experiments are open to an alternative explanation: whenever a subject must chose between a familiar comparison stimulus and a novel comparison stimulus, a preference for the familiar stimulus would result in good matching performance when the standard stimulus is familiar, but poor matching performance when the standard stimulus is novel. It seems likely that such a preference for the familiar comparison stimulus would exist in the earlier experiments, because pecks at the familiar comparison stimulus had previously been reinforced (when it matched the standard), but pecks at the novel comparison stimulus had never been reinforced.

The present study was undertaken to evaluate the three hypotheses regarding what is learned by pigeons in solving the matching-to-sample problem. Three different procedures were used in attempts to overcome the problem of possible preferences for familiar comparison stimuli over novel comparison stimuli, in novel stimulus configurations. In Experiment I, pigeons were first trained to match stimuli on one stimulus dimension (form or color), and then shifted to matching problems involving a completely new set of stimuli from the other dimension (color or form). Experiments II, III, and IV included a total for four tests of the effect of prior reinforcement of pecks at a novel stimulus on subsequent matching of that stimulus. Experiment II included transfer tests involving novel stimulus configurations constructed with standard and incorrect comparison stimuli that were both familiar from previous matching training, but which had not previously appeared in the same configuration.

EXPERIMENT I

If pigeons learn a generalized matching concept, then learning to match stimuli from one stimulus dimension (e.g., form) should result in positive transfer when the subjects are shifted to matching problems involving stimuli from a different dimension (e.g., color). The strongest possible evidence for a generalized matching concept would occur if matching performance on a given dimension (e.g., color) were significantly above chance in the first session of training on that dimension when that dimension was trained second, but not when that dimension was trained first.

Subjects

Eight experimentally naive female Silver King pigeons (5 to 7 yr old) were maintained at $75\% \pm 15$ g of their free-feeding body weights.

Apparatus

The birds were trained in a Lehigh Valley Electronics (Model 1519) pigeon test chamber, which had a dim houselight mounted above the center key. The three transparent plastic response keys were mounted behind 2.5-cm diameter circular openings in the front panel, 8.2 cm apart center to center. Inline digital

display cells (L.V.E. pattern No. 696, with #1820 lamps) could transilluminate each of the response keys with discs of colored light (red, blue, green, yellow, or white) or with geometric forms (triangle, circle, cross, square). The forms were constructed with 2.5 mm white lines on a dark background. (The maximum outside dimensions of the circle, square and cross were 16 mm; 18 mm was the maximum outside dimension of the triangle). External noises were masked by an air blower in the test chamber and a white noise in the test chamber room. Scheduling and recording equipment were located in a different room.

Procedure

Four birds (H1, H2, H3, and H4) were trained first to match colors (red, blue, and green) and then shifted to forms (triangle, circle, and cross); the other four birds (G1, G2, G3, and G4) were trained first to match forms and then shifted to colors.

All birds were trained initially to peck at white light on the center key by the method of successive approximations. Every peck was reinforced (CRF) for two days, with 30 reinforcements per day. Then for two sessions, stimuli from the first dimension to be trained were presented one at a time on each of the three keys, in a random order, until pecks at each of the three stimuli had been reinforced three times on each key (27 total reinforcements per session). Matching training was started on the next day.

Matching-to-sample sessions consisted of 120 trials, 40 trials with each of the three standard stimuli, with 12 different stimulus configurations presented in each of 10 randomized blocks. At the start of each trial, the standard stimulus illuminated the center key automatically. A single peck on the center key turned on the comparison stimuli on the two side keys, while the standard stimulus remained on the center key (simultaneous matching procedure). A single peck on either side key turned off all three stimuli and the houselight, and initiated a 15-sec blackout during which pecks had no scheduled effects. If the choice was correct it was reinforced by allowing the bird 2-sec access to mixed grain. Excess pecks at the center key were recorded, but had no scheduled effect.

Training on the first dimension continued for at least 10 sessions after the first session on which a 90% correct criterion was reached. Birds trained on colors first received 25 to 32 sessions before the shift to the form dimension, whereas birds trained on forms first had 61 to 74 sessions before the shift to the color dimension. On the day after training on the first dimension was completed, each bird was given one session in which the three stimuli from the second dimension were presented one at a time on each of the three keys, in a random sequence, until the bird had collected reinforcement three times for pecking at each of the three stimuli on each of the three keys. Matching training on the second dimension was started the next day, and continued at least until a 90% correct criterion was reached (or for 70 sessions for Bird #H2, which never reached criterion on forms).

RESULTS

Acquisition of matching took longer for forms than for colors in all eight subjects. The overall median number of sessions required to reach the 90% criterion was 12.5 for colors, and 45.0 for forms.

Figure 1 shows the group mean acquisition curves for color matching. The groups did not differ significantly in performance on the first day of color matching, nor did they differ significantly in the number of sessions required to reach either an 80% or a 90% matching criterion. However, when the acquisition data are pooled over the first six days of training, the group with prior training on form matching (G birds) was superior to the group that had not had prior matching training (H birds), t (6) = 3.70, $p < 0.01$ (one-tailed test). Thus, there is evidence that prior training on form matching will facilitate subsequent acquisition of color matching, at least in the early sessions of training.

Figure 2 shows the group average acquisition curves for form matching. The data for Bird H2 were omitted from the calculation of the average curve for the birds with prior training on color matching: Bird H2 was considered to be a drastically atypical bird, in that whereas all of the other birds in the experiment had reached a 90% criterion on forms within 24 to 53 sessions, Bird H2 was still matching forms at a chance level after 70 sessions. (With additional training in Experiment II, Bird H2 had not yet reached even an 80% criterion after 111 total training sessions with
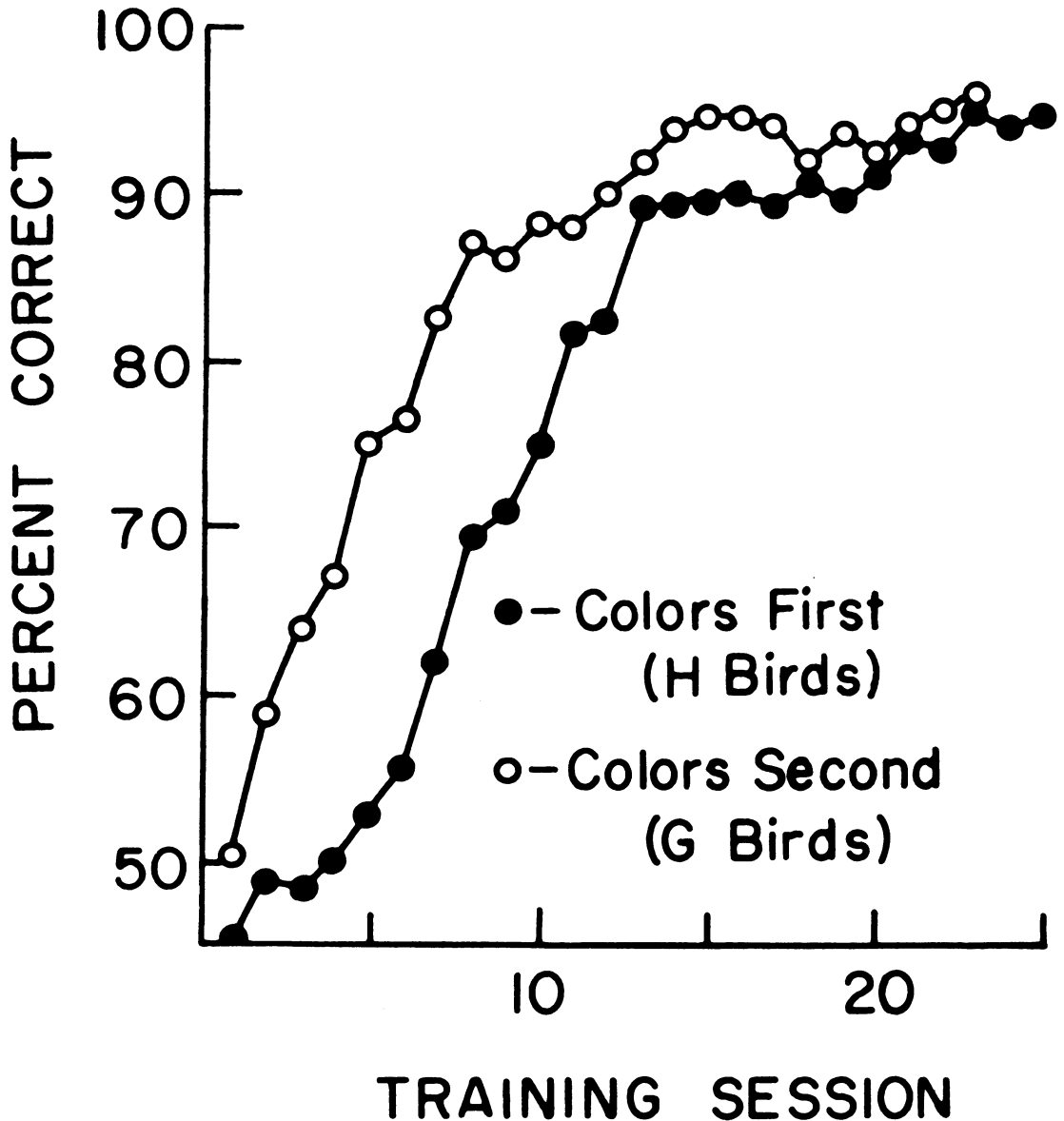
Fig. 1. Mean color-matching acquisition curves for the group trained first on form matching and then transferred to color matching (G birds) and the group trained first on color matching without prior matching experience (H birds), Experiment I.

forms.) All subjects performed at a chance level on forms for the first seven sessions or more, and even with Bird H2 omitted, the groups did not differ significantly in the number of sessions required to reach either an 80% or 90% matching criterion on forms. However, with Bird H2 omitted from the calculations and the acquisition data pooled over the first 30 sessions, the group with prior training on color matching (H birds) was superior to the group without prior matching training (G

birds), $t(5) = 2.67$, $p < 0.025$ (one-tailed test). Thus, there is weak evidence, at best, that prior training on color matching will facilitate subsequent acquisition of form matching.

An additional finding of some interest concerns position preferences on the first day of training with each dimension. On the first day of color matching, when colors were trained first, an average of 87.3% of the choice responses were to the preferred side, compared to only 67.1% when colors were trained sec-
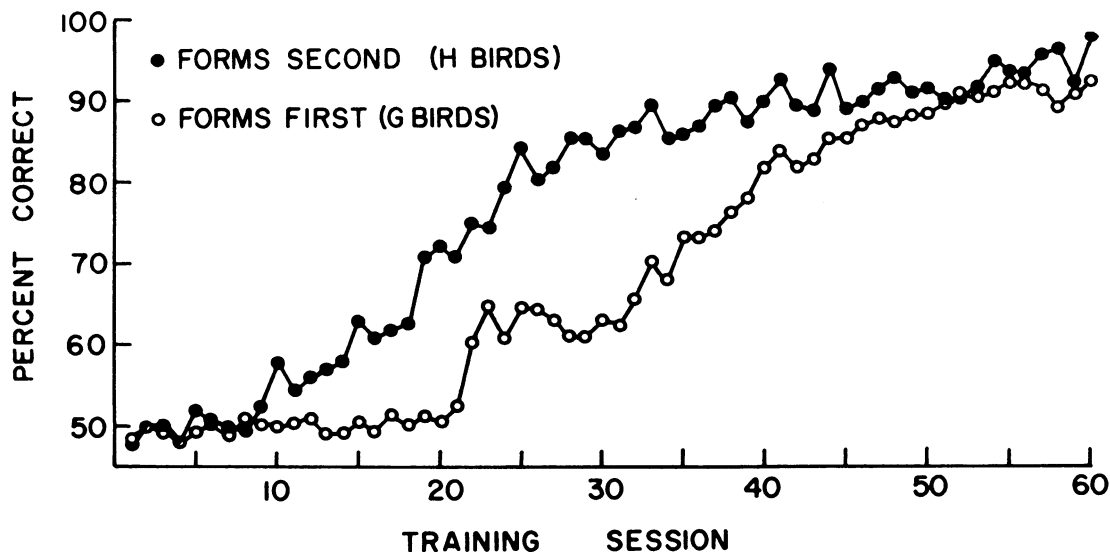
Fig. 2. Mean form-matching acquisition curves for the group trained first on color matching and then transferred to form matching (H birds) and the group trained first on form matching without prior matching experience (G birds), Experiment I.

ond, t (6) = 3.50, p < 0.02 (two-tailed test). However, there were no significant differences between the groups in position preferences on the first day of form matching (75.6% to the preferred side when forms were trained first, 84.4% when forms were trained second).

There was some evidence that the birds were able to distinguish between the three color stimuli on the first day of color-matching training, in that four of the birds had marked preferences or aversions for one of the color stimuli. If there were no preferences or aversions for any stimulus, then each stimulus should have been responded to on 50% of the trials where it appeared as a comparison stimulus. However, on the first day of color-matching training, Bird G1 chose green on 81.2% of the 80 trials where it appeared as a comparison stimulus, and Bird G4 chose red on 80% of the trials where it appeared as a comparison stimulus. On the other hand, red was chosen on only 1.2% and 22.5% of its trials as a comparison stimulus, by Birds G3 and H2, respectively. (On the first day of form-matching training the biggest deviation from chance selection was the 33.8% choice of circle in Bird G1.)

Some interesting and unexpected observations were made concerning the number of excess pecks at the standard stimulus on the center key. Only one peck on the center key was necessary in order to turn on the comparison stimuli, and additional pecks had no sched-

uled effect. However, the birds often made excess pecks on the center key, and there were some fairly consistent relationships between the relative frequency of such pecks and the stage and dimension of matching training.

Figure 3 (left panel) shows individual data for the mean number of excess pecks on the center key per session, during different stages of matching acquisition. (Since there were 120 trials per session, the number of excess pecks is equal to the total number of pecks at the center key minus 120.) The data were grouped into three acquisition stages: (1) chance performance stage, consisting of all sessions before matching performance rose to consistently 60% correct or better; (2) improving performance stage, including all consecutive sessions during which matching performance was between 60% and 80% correct; and (3) high performance stage, including all consecutive later sessions where matching performance was consistently above 80% correct. All of the data points in Figure 3 (left panel) are based on six or more sessions for forms, and three or more sessions for colors, except that for colors Birds G2 and G4 had only one session in Stage 1 and Bird G3 had only one session in Stage 2. (For each bird, the first matching session at the beginning of the experiment was eliminated from these calculations, since there was typically an unusually large number of excess center key pecks during this first session.)
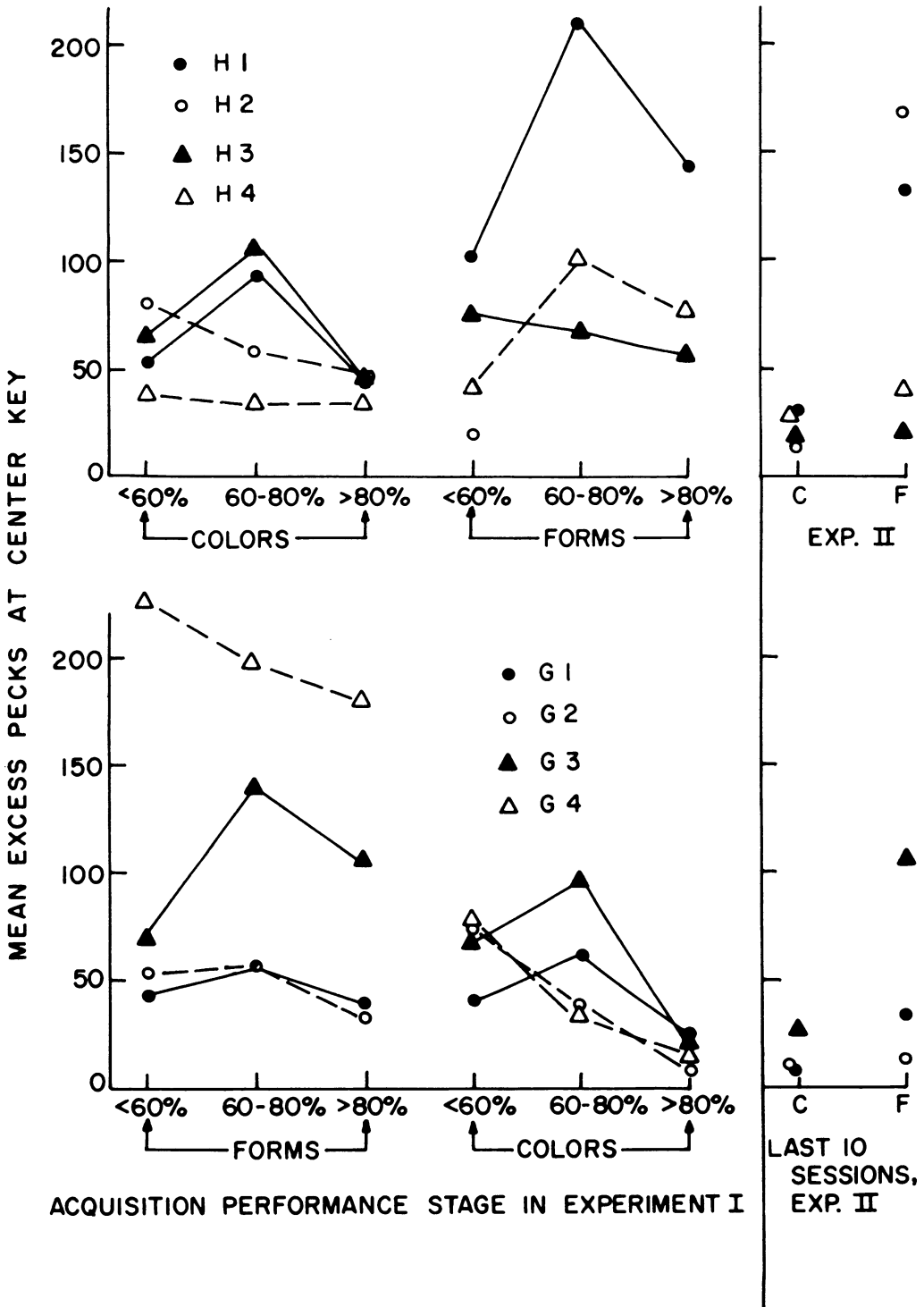
Fig. 3. Left panel: the mean number of excess pecks on the center key during three stages of matching acquisition, for individual subjects in Experiment I. Right panel: the mean number of excess pecks on the center key during the last 10 sessions of color matching (C) and form matching (F), for individual subjects in Experiment II. See text for further explanation.

It might be expected that during matching acquisition excess pecking on the center key would show a steady decline, simply as a result of extinction of excess pecks that have no scheduled consequences. In fact, all eight birds made many more excess pecks on the first day of matching training (mean 206.0) than on the second day of matching training (mean 46.5). Figure 3 shows that excess center-key pecking decreased from acquisition Stage 2 to Stage 3 in seven of eight birds during color matching, and in seven of seven birds in form matching (excluding H2). However, it is surprising that excess center-key pecking increased form acquisition Stage 1 to Stage 2 in four of eight birds during color matching, and five of seven birds during form matching, and some of these increases were relatively large (especially notice H1, H4, and G3 on forms).

Figure 4 shows matching acquisition and excess center-key peck data, session by session, for two individual birds, H1 and G3. These two birds were typical in their matching acquisition, although the difference in frequency of excess center-key pecks between different ac-

quisition stages was clearer for these birds than for most of the other birds.

All seven of the birds that reached acquisition Stage 3 on both dimensions averaged more excess pecks on the center key during Stage 3 form sessions than during Stage 3 color sessions. For these birds, during the last five sessions of training on each dimension there were 82.6 mean excess pecks per session with forms (matching was 93.0% mean correct) and only 28.0 mean excess pecks with colors (95.6% correct matching). During these last five sessions on each dimension, Bird H2 had 95.2% mean correct with 28.6 mean excess pecks during color matching, but only 50.7% mean correct with only 10.0 mean excess pecks during form matching. (Experiment II presents additional data on excess center-key pecks during form *versus* color training for these birds.)

DISCUSSION

Experiment I provides some support for the hypothesis that during matching-to-sample training, pigeons learn a generalized matching concept, in that in color matching Sessions 1 to
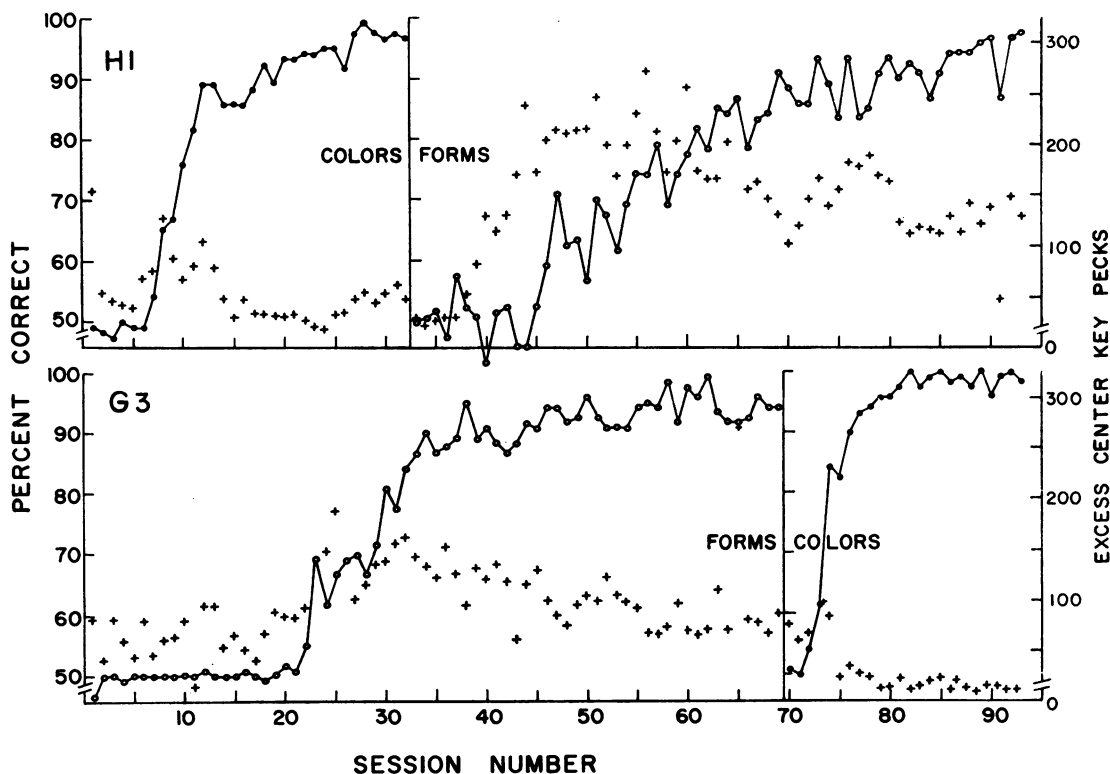

Fig. 4. Color- and form-matching acquisition data (circles), and the number of excess pecks on the center key in each session (crosses), for two subjects in Experiment I.

6 pooled, the group that had previously been trained to match forms (G birds) performed significantly better than the group without any previous matching training (H birds). This difference represents the fact that the H birds performed at a chance level during the first five or six color matching sessions, whereas the G birds performed at a chance level only during the first session. The overall slopes of the acquisition functions (Figure 1) were about the same for the two groups, once matching had begun.

The failure of the birds with prior form-matching training to match colors at an above-chance level on the first day of color-matching training cannot be attributed to the birds' inability to distinguish between the three color stimuli, since three of the four G birds had a marked preference or aversion for one of the stimuli on the first day of color-matching training. On the other hand, the relatively large amount of training required by all of the birds to learn form matching might very well be attributed to the difficulty of the discrimination between the three form stimuli.

The hypothesis that pigeons learn a generalized matching concept is contradicted by the facts that the group with prior form-matching training did not match colors at an above chance level on the first day of color-matching training, and the fact that the slope of the acquisition function was not steeper in this group than in the group without previous matching training. The observed difference between the groups in performance during the first six color matching sessions might be due to transfer of some tendency to attend to the stimuli presented on the response keys in the group with prior matching training. Eck, Noel, and Thomas (1969) demonstrated that acquisition of a successive wavelength discrimination was facilitated by prior training on a successive line tilt discrimination. Thomas (e.g., 1970) has suggested that during discrimination training pigeons learn "generalized attention", which may transfer to other discrimination problems. The superiority of the G birds over the H birds in the first six sessions of color-matching training might be due to the transfer of generalized attention in the G birds, rather than a generalized matching concept.

An interesting and unexpected finding of Experiment I (and also Experiment II, which employed the same subjects) was that the birds made more excess pecks on the center key during asymptotic form-matching sessions than during asymptotic color-matching sessions. These data can be explained if it is assumed that the excess center-key pecks are a by-product of receptor-orienting responses (or observing responses) directed at the standard stimulus. Maki and Leuin (1972) showed that the duration of the standard stimulus exposure required to maintain a high level of matching performance is greater for form stimuli than for color stimuli in pigeons. Similarly, in the present study, the greater number of excess center-key pecks during form matching than during color matching may be due to a greater number of receptor-orienting responses being required for successful performance on the relatively difficult form-matching problems than on the relatively easy color-matching problems.

In some of the birds in Experiment I, excess pecking on the center key increased during the sessions when performance rose from chance to 60 to 80% correct, and then decreased with further training (Figure 3). This finding is similar to the results of an experiment by D'Amato, Etkin, and Fazzaro (1968) with monkeys, in which the frequency of overt cue-producing responses increased during initial acquisition of a difficult visual discrimination, and then decreased during additional training sessions (in two of four subjects). These results suggest that the frequency of extra receptor-orienting or cue-producing responses may be increased during discrimination acquisition as a result of the greater frequency of reinforcement, which is an indirect result of greater exposure to the discriminative stimuli; these responses later decrease in frequency with extended training, as the subject becomes more efficient and the extra receptor-orienting or cue-producing responses become unnecessary for good discrimination performance.

EXPERIMENT II

In Experiment II, birds with extensive training in both color matching and form matching were given several transfer tests involving various types of novel stimulus configurations. To determine the effect of a novel standard stimulus or a novel incorrect comparison stimulus, in Test 1 a novel yellow stimulus was substituted for blue in a session involving red, green,

and yellow stimuli, whereas in Test 2 a novel square stimulus was substituted for the triangle in a session involving circle, cross, and square stimuli.

Before Tests 1 and 2 some of the birds were given reinforcers for pecks at the novel stimulus. If poor matching of a novel standard stimulus is due to the birds having a tendency to peck at the familiar comparison stimulus rather than the novel comparison stimulus, simply because only pecks at the familiar comparison stimulus had previously been reinforced, then reinforcement of pecks at the novel stimulus before the test session should improve matching of that stimulus.

In another attempt to control for the birds' possible preferences for the familiar comparison stimulus in a novel configuration, Tests 3 and 4 employed novel stimulus configurations that were constructed with color and form stimuli that were all familiar from previous matching training, but which had not previously been combined in the same configuration. Test 3 involved red, green, and circle stimuli, whereas Test 4 involved triangle, cross, and blue stimuli. Test 5 employed a semi-novel yellow stimulus in configurations with the familiar triangle and cross stimuli, in order to determine whether a high level of performance on novel configurations in Test 4 could be attributed simply to the very easy discrimination between the blue and form comparison stimuli.

Subjects and Apparatus

Seven of the birds from Experiment I were used. Bird #G4 died at the end of Experiment I. The apparatus was the same as Experiment I.

Procedure

Following Experiment I, the matching dimensions were reversed two more times, so that each bird had about 18 additional sessions of training on each dimension. Then, each bird was given from 20 to 32 sessions of training in which the color and form dimensions were alternated every other session. Before the first transfer test session, the birds had had 60 median total sessions of training on color matching and 95 median total sessions of training on form matching, counting training in both Experiments I and II.

Transfer tests 1, 2, and 3 were given in different sequences for different birds. The test sessions were like normal 120-trial training sessions except for the specific stimuli employed, and each correct matching response was reinforced. The tests were separated by eight to 12 sessions of additional training (four to six sessions on each dimension).

On the day before Test 1, four of the birds were given 60 reinforcers (CRF) for pecking the novel yellow stimulus, with yellow presented 20 times on each of the three keys, in a random sequence. The same procedure was followed for four birds with the novel square stimulus on the day before Test 2.

Tests 4 and 5 were given after Tests 1, 2, and 3 had been completed. Four birds received Test 4 first, and three received Test 5 first. Two days before Test 5, the three birds that had not had prior CRF for pecks at yellow received 60 reinforcers for pecks at yellow, as described above.

For all birds, the last training session before Test 1 was with colors, the last session before Tests 2, 4, and 5 was with forms, and three had colors and four had forms before Test 3.

RESULTS

During the last four training sessions on each dimension before the first transfer test, the mean performance was 96.6% correct for colors and 91.6% correct for forms (excluding H2). Because Bird H2 never reached an 80% matching criterion on forms, its data were included in the analysis only for Test 1, the only test that did not involve any form stimuli. (Bird H2 had always been in the $n = 4$ groups in the experimental treatments and counterbalancing procedures; these groups were reduced to $n = 3$ with H2 omitted.)

In Test 1, where a novel yellow stimulus was substituted for blue in a session with red, green, and yellow stimuli, birds ($n = 4$) that had previously collected reinforcement for pecks at yellow averaged 65.5% correct (three birds were above chance, one below chance) on trials with the yellow standard stimulus, whereas birds ($n = 3$) that had not previously collected reinforcement for pecks at yellow averaged only 23.2% correct (all birds below chance), a significant difference, $t(5) = 3.17$, $p < 0.025$ (one-tailed test). In Test 2, where a novel square was substituted for the triangle in a session with circle, cross, and square, birds

Table 1

Mean per cent correct matching responses for each of three types of stimulus configurations in each transfer test in Experiment II.

Configurations: Standard St./Incorrect Comparison St.		t-tests
Test 1 (red, green, yellow):		
a. familiar color/familiar color	94.3	a vs. b: N.S.**
b. familiar color/novel color	96.8	a vs. c: t (6) = 3.99, p < 0.01**
c. novel color/familiar color	47.5	
Test 2 (circle, cross, square):		
d. familiar form/familiar form	94.6	d vs. e: t (5) = 1.54, N.S.**
e. familiar form/novel form	89.6	d vs. f: t (5) = 5.72, p < 0.01**
f. novel form/familiar form	52.5	
Test 3 (red, green, circle):		
g. familiar color/familiar color	95.8	g vs. h: N.S.**
h. familiar color/familiar form	97.1	h vs. i: t (5) = 3.96, p < 0.02**
i. familiar form/familiar color	78.8	
Test 4 (triangle, cross, blue):		
j. familiar form/familiar form	90.4	j vs. k: N.S.**
k. familiar form/familiar color	90.8	k vs. l: t (5) = 3.37, p < 0.02**
l. familiar color/familiar form	95.0	h vs. l: N.S.**
		i vs. k: t (5) = 2.17, N.S.**
Test 5 (triangle, cross, yellow):		
m. familiar form/familiar form	89.6	m vs. n: t (5) = 1.63, N.S.**
n. familiar form/seminovel color	93.3	l vs. o: t (5) = 2.20, p < 0.05*
o. seminovel color/familiar form	80.4	

*one-tailed test; **two-tailed test

(n = 3) that had previously collected reinforcement for pecks at the square averaged 51.7% correct on trials with the square standard stimulus, whereas birds (n = 3) that had not received prior reinforcement for pecks at the square averaged 54.2% correct, a nonsignificant difference. Because the effect of prior reinforcement for pecks at the novel yellow stimulus was not replicated in a subsequent experiment (Experiment IV), the data for all seven birds were combined in further analyses of the results of Tests 1 and 2.

Table 1 shows the mean per cent correct matching responses for each of three types of stimulus configurations in each of the five transfer tests. In Tests 1 and 2, the three types of stimulus configurations were: (1) familiar standard stimulus/familiar incorrect comparison stimulus (configurations a and d in Table 1); (2) familiar standard stimulus/novel incorrect comparison stimulus (configurations b and e); and (3) novel standard stimulus/familiar incorrect comparison stimulus (configurations c and f).

In both Test 1 with colors and Test 2 with forms, mean performance on novel configura-

tions consisting of a familiar standard stimulus and a novel incorrect comparison stimulus was as good as performance on familiar configurations (a versus b and d versus e in Table 1). However, in both tests, performance on novel configurations with a novel standard stimulus dropped to a chance level, and was significantly worse than performance with familiar configurations (a versus c and d versus f). Thus, a novel stimulus will disrupt matching if it appears as the standard stimulus, but not if it appears as the incorrect comparison stimulus.

In Tests 3 and 4, there were no novel stimuli, but novel stimulus configurations were produced by combining familiar colors with familiar forms for the first time. In Test 3, a familiar color was matched just as well in a novel configuration as in a familiar configuration (g versus h in Table 1). Similarly, in Test 4, a familiar form was matched just as well in a novel configuration as it was in a familiar configuration (j versus k). (Some incidental results: in both Test 3 and Test 4, a familiar color was matched in a novel configuration better than a familiar form was matched in a

novel configuration (*h versus i* and *k versus l*). Also, performance on the novel configuration involving a familiar form standard was better in Test 4 than in Test 3 (*i versus k*), though this difference was not quite significant.)

Matching of the familiar blue standard stimulus in Test 4 was significantly better than matching of the seminovel yellow standard stimulus in Test 5 (*l versus o*).

The right panel in Figure 3 shows the mean number of excess center-key pecks per session during the last 10 color (C) and form (F) matching sessions for individual subjects in Experiment II. During the last 10 training sessions on each dimension, all birds made more excess pecks on the center key during form-matching sessions than during color-matching sessions. The six birds that had a high level of performance on both dimensions had a mean of 96.8% correct, while they made 20.6 mean excess pecks on the center key per session during color-matching sessions; for form matching, they had a mean of 92.9% correct, while they made 56.8 mean excess center-key pecks. During these last training sessions, Bird H2's form-matching performance finally rose to a mediocre 74.1% level while it made 168.0 mean excess pecks at the center key per session (compared to only 19.0 mean excess pecks in Experiment I, where form matching was below 60% correct); but H2's color matching was 97.9% correct with only 13.3 mean excess pecks at the center key.

DISCUSSION

In Experiment II, matching performance was disrupted by a novel standard stimulus but not by a novel incorrect comparison stimulus (Tests 1 and 2). Further, matching was not disrupted by novel stimulus configurations involving familiar form and color stimuli that had not previously been combined in the same configuration (Tests 3 and 4). These results suggest that matching performance in pigeons does not depend simply on the learning of a set of discriminations based on the specific stimulus configurations that appear during training.

Matching of the familiar blue standard stimulus was significantly better than matching of the seminovel yellow standard stimulus, in novel configurations with familiar forms as incorrect comparison stimuli (Tests 4 and 5, *l versus o*). This result demonstrates that the

good matching performance with the familiar blue in a novel configuration was not due merely to the ease of the discrimination between the color and form comparison stimuli: the discrimination between blue *versus* forms should have been no easier than the discrimination between yellow *versus* forms. Apparently, the good matching performance with the familiar blue standard in a novel configuration was due to the birds' prior matching training with a blue standard stimulus.

In Test 1, matching of the novel yellow stimulus was facilitated by prior reinforcement of pecks at that stimulus. However, reinforcement of pecks at a novel square had no effect on subsequent matching of the square in Test 2. Perhaps prior reinforcement of pecks at the novel stimulus had an effect in Test 1, but not in Test 2, because it was easier for the birds to discriminate among the three color stimuli in Test 1 than among the three form stimuli in Test 2. Experiment III included another test of the effect of prior reinforcement of pecks at a novel stimulus on subsequent matching of that stimulus.

EXPERIMENT III

The primary purpose of Experiment III was to determine the effect of prior reinforcement of pecks at a novel stimulus upon subsequent matching of that stimulus. Pigeons were first trained to match stimuli on the color dimension, and then some of the birds were given reinforcers for pecking at a novel form. Finally, all of the birds were given matching training involving the novel form and two of the familiar colors. (The first matching session with the novel form is referred to as transfer Test 6, continuing the test numbering sequence from Experiment II.) A form (white lines on a black background) was used as the novel stimulus, instead of a novel color, in order to ensure maximum discriminability between the familiar stimuli and the novel stimulus, and to make it unlikely that any successful matching of the novel stimulus could be attributed simply to generalization from one of the familiar stimuli.

After the birds had learned to match the form, the now familiar form was presented in configurations with new novel forms. This transfer test with three forms (Test 7) included a type of configuration that had not been included in any of the tests in Experiment II: a

novel standard stimulus combined with a novel incorrect comparison stimulus.

Subjects and Apparatus

Nine experimentally naive female Silver King Pigeons were maintained as in Experiments I and II and trained in the same apparatus used in Experiments I and II.

Procedure

Following the same simultaneous matching procedure employed in Experiment I, the nine birds were trained to match three colors (red, green, and blue) for at least 28 sessions beyond a 90% correct criterion (49 median total sessions). They were then divided into three groups of three birds each (matched for amount of training), and birds in the different groups were given either 3, 27, or 270 total reinforcers for pecks at a novel form stimulus. One bird in each group had a triangle, circle, or cross as the novel form. The form was presented on each of the three keys, in a random sequence; each peck at the form was reinforced (CRF), and caused the form to be switched to a different key. Subjects in the three groups received either 1, 9, or 90 reinforcers per day, respectively, on each of three successive days. The birds were then given matching training with the novel form and the familiar red and green stimuli for 15 sessions (the first session of this training was transfer Test 6). Finally, all of the birds were given a matching session (transfer Test 7) involving all three forms: in this test session one of the forms was now fa-miliar from previous matching training, whereas two of the forms were novel.

RESULTS

In Test 6, involving the novel form and the familiar red and green stimuli, the form was matched at below chance level by all subjects, and there was no significant difference in performance among the three groups. The overall mean per cent correct for each of the three types of configurations in Test 6 is shown in Table 2. There was no difference among the groups in the number of sessions required to reach an 80% correct criterion for matching the form (overall mean: 3.6 sessions).

In Test 7, involving three forms, eight of the nine birds matched their now familiar form at better than a chance level. The mean per cent correct for each of the three types of configurations in Test 7 is shown in Table 2. (In configuration *t*, seven birds matched at below chance level and two at chance; in configuration *u*, eight birds were below chance and one was at chance.)

DISCUSSION

Experiment III presents several puzzles. Not only did prior reinforcement of pecks at a novel form stimulus fail to have any effect on subsequent matching of that stimulus, but all birds matched the novel form at below chance level in the first session in which it appeared as a standard stimulus (Test 6). The below-chance performance with the novel form standard stimulus is in contrast to the results of

Table 2

Mean per cent correct matching responses for each of three types of stimulus configurations in transfer Tests 6 and 7 (Experiment III) and Test 8 (Experiment IV).

Configurations: Standard St./Incorrect Comparison St.		t-tests
Test 6 (red, green, form):		
p. familiar color/familiar color	96.1	p vs. q: N.S.**
q. familiar color/novel form	95.0	p vs. r: t = 15.98, p < 0.01**
r. novel form/familiar color	17.8	
Test 7 (triangle, circle, cross):		
s. familiar form/novel form	80.3	s vs. u: t = 4.88, p < 0.01**
t. novel form/familiar form	36.9	t vs. u: t = 1.10, N.S.**
u. novel form/novel form	31.9	
Test 8 (red, green, yellow)		
v. familiar color/familiar color	88.0	v vs. w: t = 1.78, N.S.**
w. familiar color/novel color	83.5	v vs. x: t = 4.61, p < 0.01**
x. novel color/familiar color	29.7	

**two-tailed tests, all df = 8

Tests 1 and 2 (*c* and *f* in Table 1), where the overall mean matching performance with a novel standard stimulus was at a chance level.

Another surprising result was in Test 7 with three forms, where matching performance was typically below a chance level in the configurations that involved a novel standard stimulus (*t* and *u* in Table 2), whether or not the incorrect comparison stimulus was familiar or novel.

Before the data from Experiment III are discussed further, Experiment IV is presented. Experiment IV attempted to replicate Test 1 of Experiment II, in which a novel yellow stimulus was presented in configurations with familiar red and green stimuli.

EXPERIMENT IV

Experiment IV was another test of the effect of reinforcement of pecks at a novel stimulus on subsequent matching of that stimulus. Following matching training with red, green, and blue stimuli, some of the birds were given reinforcers for pecks at a novel yellow stimulus, presented alone. During the sessions when yellow was presented alone, it was presented only on the side keys, and never on the center key. This procedure was used to reduce the likelihood that below-chance matching of yellow would occur simply as a result of extinction of previously reinforced responses to yellow on the center key leading to a choice of the non-yellow stimulus (a possibility first suggested by Berryman, Cumming, Cohen, and Johnson, 1965). In transfer test session (Test 8) the birds were presented with configurations involving the novel yellow stimulus and familiar red and green stimuli (as in Test 1 of Experiment II).

Subjects and Apparatus

Nine experimentally naive female Silver King pigeons were maintained and trained in the same apparatus as in the previous experiments.

Procedure

In preliminary training, the birds were first trained to peck at one of the colors (red, green, or blue) on either the left or the right key. Then, for three successive days, the red, green, and blue stimuli were presented on the left and right keys (never on the center key) in a random sequence, for a total of five presentations of each stimulus on each key, and each

peck on the illuminated key was reinforced (30 total reinforcements per day).

Following preliminary training, the birds were trained on a simultaneous color-matching procedure as in the previous experiments. Although originally a 90% correct criterion was set, four of the birds that had not reached this criterion after 22 or more sessions were tested at this point. All of the birds were trained for at least nine sessions beyond an 80% criterion, and the mean matching performance was 89% correct in the last training session before the first transfer test session. Before the first transfer session, three groups were formed (n = 3 each), matched for amount of training and performance in the last training session. Subjects in the three groups were given either 0, 30, or 180 total reinforcers (CRF) for pecks at a novel yellow stimulus. The 30 CRF and 180 CRF groups were given 10 or 60 reinforcers, respectively, for pecks at yellow, on each of three successive days. Yellow appeared equally often on each of the two side keys (but never on the center key), and each peck at yellow was reinforced. Birds in the zero CRF group were not exposed to the yellow stimulus during the time when the other birds were getting CRF training; they were simply put in the dark test chamber for 10 min on each of three successive days. Finally, all birds were given matching training with the novel yellow stimulus and the familiar red and green stimuli. (The first matching session with the novel yellow stimulus is referred to as Test 8.) Transfer training continued until all of the birds reached an 80% correct criterion for matching the yellow stimulus.

RESULTS

In the first transfer session (Test 8), the three groups did not differ significantly in the number of correct matches of the novel stimulus. Seven of the birds matched yellow at less than chance level (range 2.5% to 37.5% correct for these birds), and only two birds matched yellow at better than chance level (92.5% for one bird in the 180-CRF group; 55% for one bird in the 0-CRF group). The overall mean per cent correct for the three types of configurations in Test 8 is shown in Table 2. The three groups did not differ significantly in the mean number of sessions required to reach an 80% correct criterion for matching the novel yellow stimulus (overall mean 6.3 sessions). The over-

all mean per cent correct matching responses with the novel yellow standard stimulus in Test 8 (x in Table 2) was not significantly different from the mean performance with the novel yellow standard stimulus in Test 1 (c in Table 1), t (14) = 1.25.

DISCUSSION

In Test 8, prior reinforcement of pecks at a novel yellow stimulus had no effect on subsequent matching of that stimulus. Out of a total of four attempts (Tests 1, 2, 6, and 8), only in Test 1 did prior reinforcement of pecks at a novel stimulus seem to improve subsequent matching of that stimulus. Rather than speculating on the unique combination of conditions in Experiment II that caused the results of Test 1 to differ from the results of Tests 2, 6, and 8, it seems safer to conclude that, in fact, prior reinforcement of pecks at a novel stimulus does not have any effect on subsequent matching of that stimulus. The apparent effect found in Test 1 may have been due to sampling error.

In Experiments III and IV, novel stimuli were typically matched at below chance level (configurations r, t, u, and x in Table 2). In other words, when the standard stimulus was novel, the birds usually chose the nonmatching comparison stimulus. This result is consistent with an observation by Berryman et al. (1965) that in a transfer test during simultaneous oddity training (where choice of the nonmatching comparison stimulus was reinforced), performance with a novel standard stimulus was usually better than chance. Also, a novel yellow standard stimulus was matched at less than chance level by all three subjects in a zero-delay matching experiment (Cumming et al., 1965).

When matching of a novel stimulus is reliably below a chance level (e.g., Test 6), one contributing factor is undoubtedly simple generalization decrement: pigeons are more likely to peck at a familiar comparison stimulus, responses to which have previously been reinforced, than they are to peck at a novel comparison stimulus, without a history of reinforcement. However, a familiar comparison stimulus has a unique status that depends on some or all of several factors in addition to the fact that responses to it have previously been reinforced: for example, responses to it have sometimes been extinguished (when mismatch-

ing occurs), and it has held a particular position in a stimulus-response chain that has ended in reinforcement, and it has been presented in configurations with certain other stimuli. Merely reinforcing responses to a novel stimulus is not sufficient to make that stimulus familiar in the context of a stimulus configuration in a matching problem.

That mismatching of a novel standard stimulus is not due entirely to generalization decrement is suggested by the fact that in Test 7, matching of a novel form was usually below chance level even when both the correct and incorrect comparison stimuli were novel (configuration u in Table 2). Also, in the present study, a total of 19 of 22 birds without previous matching training performed at slightly less than chance level in their first session of color-matching training (three of four H birds in Experiment I, eight of nine birds in Experiment III, and eight of nine birds in Experiment IV; overall mean 47.1% correct). A possible explanation of these observations has been suggested by Berryman et al. (1965), who pointed out that a pigeon's initial tendency to choose the nonmatching comparison stimulus may be due to the fact that a trial begins with a peck at a particular standard stimulus going unreinforced, which consequently decreases the probability that the bird will peck at the same stimulus again when it appears as one of the comparison stimuli immediately following the response to the standard stimulus. This initial tendency to mismatch usually does not last very long, because responses to the nonmatching comparison stimulus are never reinforced, whereas responses to the matching comparison stimulus are reinforced.

GENERAL DISCUSSION

The bulk of the evidence from the present study supports the hypothesis that in solving the matching-to-sample problem, pigeons learn a set of specific stimulus-response chains, rather than a general matching concept or a set of discriminations based on specific stimulus configurations.

The possibility that pigeons solve the matching-to-sample problem by learning a set of discriminations based upon the specific stimulus configurations is disproven by the fact that matching is not necessarily disrupted by a novel stimulus configuration. In Tests 1, 2, 6, and 8, a familiar standard stimulus was

matched just as well in configurations with a novel incorrect comparison stimulus as in familiar configurations with a familiar incorrect comparison stimulus. (This result was also obtained in earlier experiments by Cumming and Berryman, 1961, and Cumming *et al.*, 1965). Furthermore, the present study demonstrated that this failure of a novel incorrect comparison stimulus to disrupt matching was not due simply to the pigeons' tendency to choose a familiar comparison stimulus over a novel comparison stimulus: in Tests 3 and 4, familiar standard stimuli were matched just as well in novel configurations involving familiar incorrect comparison stimuli as they were in familiar configurations.

It seems very unlikely that pigeons normally learn a general matching concept during matching-to-sample training, in view of the fact that in all tests with a novel standard stimulus, matching performance was at or below chance level (Tests 1, 2, 6, 7, and 8; also Cumming and Berryman, 1961, and Cumming *et al.*, 1965). The possibility that the poor performance with a novel standard stimulus is at least partly a result of generalization decrement cannot be ruled out; the birds might tend to choose the familiar incorrect comparison stimulus over the novel correct comparison stimulus, simply because they had previously been given reinforcers for pecking at the familiar stimulus but not for pecking at the novel stimulus. However, the present study demonstrated that prior reinforcement of pecks at a novel stimulus is not sufficient, in itself, to overcome the generalization decrement and improve matching performance with the novel standard stimulus (Tests 1, 2, 6, and 8).

In Experiment I, prior form-matching training seemed to result in better performance during the first six sessions of color matching, compared to a group without prior matching experience. However, this is not strong evidence for a general matching concept, since prior form-matching training did not result in above-chance performance in the first color-matching session, nor did the groups differ in the slopes of their color-matching acquisition curves, once they started to match successfully. The difference in performance between the groups in Sessions 1 to 6 of color matching might be due to the transfer group's learning of "generalized attention" to the stimuli on

the response keys (Thomas, 1970), rather than learning a generalized matching concept.

According to the stimulus-response chaining hypothesis, pigeons solve the matching-to-sample problem by learning a set of specific stimulus-response chains, such as "peck red on the center key, then peck red on a side key", or "peck triangle on the center key, then peck triangle on a side key". The stimulus-response chain hypothesis is supported by the combined facts that in transfer tests: (1) a familiar standard stimulus was matched successfully in novel stimulus configurations, where the incorrect comparison stimulus was either a novel stimulus or a familiar stimulus that had not previously appeared in configurations with the standard stimulus; and (2) a novel standard stimulus was not matched successfully, regardless of whether the incorrect comparison stimulus was novel or familiar. The response-chaining explanation of matching is consistent with the "coding hypothesis" presented by Cumming *et al.* (1965), according to which pigeons make a specific mediating response, r_x, to each trained standard stimulus, and this mediating response directs the choice between the two comparison stimuli.

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