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TRANSFER OF MATCHING PERFORMANCE IN PIGEONS

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Three pigeons were given extensive training on three-key simultaneous matching problems using geometric-form and hue stimuli. After acquisition of matching, the birds were tested with pairs of stimuli involving one or both novel members. Matching during the test stimuli occurred less often than during the later stages of the acquisition phase, but more often than would occur if no transfer had taken place. Greater positive transfer was observed for problems that involved one, rather than two, novel stimuli. In the second phase of the experiment, previously trained birds were shifted to problems that required symbolic matching, *i.e.*, the pigeons had to associate a particular center-key stimulus with a particular side-key stimulus. On each trial, one of two simuli was presented on the center key, and two other stimuli, different from those used on the center key, were displayed on the side keys. When the problem shift was introduced, correct responding was impaired, but remained considerably above chance level and quickly recovered in following sessions. The results were interpreted as favoring a stimulus–response-chaining account of matching behavior.

Key words: matching to sample, symbolic matching, transfer, matching concept, ratio reinforcement of matching, key peck, pigeon

Transfer of training has been used to investigate the matching-to-sample behavior of pigeons. Typically, a bird is first trained on a matching problem. One stimulus, the standard, is followed by a set of stimuli (usually two) that comprise the comparison stimuli. The bird is required to respond to the comparison stimulus that matches the standard stimulus. Once the bird attains a high level of matching performance, it is shifted to a new matching problem. In this problem, novel stimuli make up one or more of the comparison stimuli; the standard stimulus may or may not be novel. Positive transfer is shown when the bird's matching performance remains stable after shifting to the new problem.

Although several studies have reported positive transfer of matching-to-sample performance by pigeons (*e.g.*, Cumming and Berryman, 1961, 1965; Farthing and Opuda, 1974; Zentall and Hogan, 1974), the occurrence of transfer seems to be related to the bird's familiarity with the transfer stimuli. In a series of skillfully designed experiments, Farthing and Opuda (1974) showed that the matching by pigeons during a transfer test was most impaired whenever a novel stimulus was used as the standard stimulus. No disruption of matching was found if a novel stimulus was a comparison stimulus, provided the standard stimulus (and the other comparison stimulus) were familiar to the subject. A similar finding (Cumming, Berryman, and Cohen, 1965) was found for matching with zero-delay. In other circumstances, however, key pecking of pigeons for food reinforcement is disrupted when a novel stimulus is presented. In the usual matching-to-sample experiment, the subject is required to respond to the standard stimulus before onset of the comparison stimuli. Perhaps the introduction of a novel standard stimulus (or a novel standard stimulus in combination with one or more novel comparison stimuli) might itself disturb the matching performance. Exposure to many matching problems with novel standard stimuli (and novel stimulus combinations) might permit a pigeon to adapt to changing stimulus situations. After such training, the bird might show positive transfer to matching problems with novel standard stimuli.

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The purpose of the first part of this experiment was to give pigeons extensive matching-to-sample training, using many different visual stimuli presented in various combinations, to determine effects on transfer to problems with novel standard stimuli and novel stimulus combinations. In the second part of the experiment, these extensively trained birds were shifted to problems that involved symbolic matching (*cf.* Cumming and Berryman, 1965) to determine if their training would transfer to this different problem.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons, obtained from the Palmetto Pigeon Plant, were maintained at 80% ±15 g of their free-feeding body weights. Birds were tested one session per day, provided their weights were within the specified ranges. On days of testing, a bird's session began at (or near) the same time.

Apparatus

A standard Lehigh Valley pigeon test chamber equipped with a three-key response panel was used. Pecks to the keys with a force of at least 0.15 N registered as responses. Each transparent key was illuminated from behind with a single plane rear-projection readout (Grason-Stadler A509-2A with 1820 lamps). A special set of geometric configurations and hues was prepared from standard BRS and Grason-Stadler pattern sets and from Kodak Wratten Filters. The insert in Figures 1 and 3 shows the stimulus displays. Wratten Filter number 45 (blue), 61 (green), 15 (amber), and 26 (red) produced hues for stimulus numbers 1, 2, 3, and 4, respectively. Stimulus numbers 5, 6, 7, and 8 were from BRS standard pattern group 693, numbers 9, 10, and 11 from Grason-Stadler standard pattern set 150, and number 12 from Grason-Stadler standard pattern set 156.

Above the center key was a 2.5-W houselight that provided dim illumination in the chamber, and below the key was a food magazine containing mixed grain. A blower mounted on the side of the chamber provided continuous masking noise. Solid-state digital logic programming and standard recording equipment were located in a separate room.

Procedure

In all phases of the experiment, the reinforcer was 4 sec access to the lighted magazine, during which all keylights were off. Fifty grain deliveries were administered in each session.

Preliminary training. In the first session, all birds were given magazine and key-peck training. Unfiltered light (white) from the readout illuminated the center key, and each peck on this key was reinforced. The side keys were dark and pecks on them had no scheduled effect.

The next day, the pigeons were trained to peck 10 times on one of the three keys for reinforcement. White light illuminated the one operative key, selected in random fashion; responses to the darkened keys were ineffective. This procedure continued for six sessions. The matching procedure was introduced in the next session.

Acquisition of matching. A matching trial started with the standard stimulus on the center key. Ten pecks to this stimulus produced the comparison stimuli on the side keys; the standard stimulus remained on the center key (a simultaneous-matching procedure). The trial terminated with a peck to either side key. Pecks to dark side keys or to the center key after the side keys had been illuminated were recorded but had no other scheduled consequence. Auditory feedback occurred for each of the 10 pecks to the center key that preceded illumination of the side keys and for responses to the side keys after they were illuminated. Each peck produced a 50-msec sounding of a Mallory Sonalert, model SC628.

A modified ratio-matching schedule determined access to the food magazine. The number of correct matches had to be completed without error. Incorrect matches were followed by a 4-sec blackout, during which the key stimuli and the houselight were turned off and key pecks had no scheduled effect; they also reset the ratio count to zero. In addition, a correction procedure for incorrect matches was employed, *i.e.*, a trial was repeated after an error until a correct match was made.

For the first 12 sessions, one pair of stimuli, randomly selected from the available hue stimuli, was used. A new pair of stimuli, the two remaining hue stimuli, were presented in the next 10 sessions and a third pair of novel stimuli (geometric forms) for the following seven sessions. All subsequent pairs of stimuli were presented for three consecutive sessions. The geometric forms projected in the third and fourth series of sessions were randomly chosen from the patterns available. Assignment of stimuli to later series of sessions in acquisition was done randomly, but within the confines of the following rules: stimuli were not to be combined if they had previously been paired together, and a stimulus was not to be used in any series in succession. The specific pairs of stimuli presented during the experiment and their order of presentation are given in Tables 1 and 2.

Within a session, the particular sequence of stimulus presentation was random and controlled by an eight-channel tape reader. Four tape loops, used during the experiment, were

Table 1

Sequence of stimulus pairs presented in acquisition, Test-1, and Posttest-1 sessions, with frequency of correct and incorrect matches for each pigeon. An asterisk indicates the introduction of a novel stimulus.

Experimental Phase and Session Number	*Stimulus Numbers*	*Bird*					
		P1		*P2*		*P3*	
		Correct	*Errors*	*Correct*	*Errors*	*Correct*	*Errors*
ACQUISITION							
1	3*, 4*	50	43	50	74	50	122
2	3, 4	50	40	50	40	50	36
3	3, 4	138	78	118	64	123	60
4	3, 4	109	14	116	11	105	18
5	3, 4	245	25	342	65	277	34
6	3, 4	202	34	308	41	316	41
7	3, 4	290	23	284	17	317	41
8	3, 4	271	14	342	53	300	32
9	3, 4	263	19	281	25	278	17
10	3, 4	271	19	300	29	270	15
11	3, 4	267	18	287	19	277	14
12	3, 4	261	10	269	8	289	20
13	1*, 2*	245	171	131	102	186	168
14	1, 2	222	73	197	137	177	54
15	1, 2	180	41	155	9	168	23
16	1, 2	333	56	266	11	258	9
17	1, 2	269	16	268	10	261	16
18	1, 2	302	41	254	3	256	8
19	1, 2	284	21	259	5	280	19
20	1, 2	256	8	255	3	260	5
21	1, 2	250	8	252	2	255	6
22	1, 2	266	15	256	3	262	16
23	5*, 6*	119	285	64	134	198	152
24	5, 6	260	60	406	177	159	33
25	5, 6	266	17	278	24	279	23
26	5, 6	270	18	283	23	262	25
27	5, 6	253	13	266	14	254	17
28	5, 6	255	14	270	22	253	8
29	5, 6	255	45	267	23	261	10
30	7*, 8*	318	236	313	341	398	283
31	7, 8	323	60	311	66	366	96
32	7, 8	275	33	299	34	285	33
33	3, 5	418	307	391	137	316	69
34	3, 5	332	53	289	22	256	2
35	3, 5	260	20	269	9	252	8
36	2, 6	268	15	296	48	304	35
37	2, 6	255	12	271	11	261	20
38	2, 6	253	4	254	4	253	21
39	1, 4	294	33	281	16	271	17
40	1, 4	282	20	257	4	250	0
41	1, 4	253	6	267	16	250	3

Table 1 *continued*

Experimental Phase and Session Number	*Stimulus Numbers*	*Bird*					
		P1		*P2*		*P3*	
		Correct	*Errors*	*Correct*	*Errors*	*Correct*	*Errors*
42	5, 7	373	125	433	128	393	123
43	5, 7	330	85	307	66	292	46
44	5, 7	296	68	304	37	294	47
45	4, 8	251	3	275	15	256	6
46	4, 8	252	6	256	6	250	6
47	4, 8	251	6	251	3	263	4
48	2, 3	351	99	339	87	408	104
49	2, 3	301	32	301	48	316	37
50	2, 3	255	7	265	12	262	18
51	6, 8	666	341	567	231	497	245
52	6, 8	292	40	390	84	284	32
53	6, 8	281	44	265	12	275	28
54	1, 5	267	11	268	17	261	8
55	1, 5	270	15	256	13	260	16
56	1, 5	264	7	250	6	261	9
57	2, 4	271	21	289	26	313	35
58	2, 4	259	8	273	14	272	18
59	2, 4	256	3	253	3	256	11
60	6, 7	325	37	349	84	275	18
61	6, 7	281	24	307	32	296	44
62	6, 7	278	18	277	24	259	37
63	1, 8	310	60	253	14	273	21
64	1, 8	260	14	253	4	252	8
65	1, 8	258	12	252	6	250	1
TEST-1							
66	10*, 12*	720	319	637	253	448	150
67	10, 12	324	73	334	77	291	35
68	10, 12	355	59	278	36	262	15
69	5, 9*	282	36	340	51	403	101
70	5, 9	258	18	253	3	279	28
71	5, 9	255	11	264	17	261	15
72	3, 11*	260	4	260	7	255	5
73	3, 11	255	5	253	4	256	9
74	3, 11	257	16	252	13	259	8
POSTTEST-1							
75	10, 12	356	55	306	55	258	16
76	10, 12	284	20	276	8	261	24
77	10, 12	281	16	255	5	283	71
78	5, 9	258	15	252	1	340	79
79	5, 9	257	16	257	4	275	26
80	5, 9	261	12	278	8	263	13
81	3, 11	258	2	251	10	255	6
82	3, 11	253	4	256	6	254	5
83	3, 11	260	11	254	5	254	6

prepared such that on every trial either stimulus had an equal chance of being the standard stimulus. A probability generator set at 0.50 determined the side for appearance of the matching comparison stimulus. The tape reader advanced only after a correct match had been made.

The ratio requirement of correct matches was expanded during the first six sessions of matching training from one (FR 1) to five (FR 5). When the second pair of stimuli was introduced, the ratio was returned to one and then increased. By the fourth session with the second pair of stimuli, all birds were responding under an FR 5. The same procedure was followed with presentation of the third pair of stimuli, except that the third session was the first full session with FR 5. In all following sessions, the ratio was started and remained at five.

During the 65 sessions of matching training, 15 pairs of stimuli were presented. Testing with novel stimuli began with the next session.

Testing for transfer: Test 1. In the first transfer test, three pairs of stimuli were each presented for three consecutive sessions (see Table 1 or Figure 1 for the specific stimuli). Random selection of stimuli determined which stimuli were paired together, as long as each pair contained at least one novel stimulus. The first pair of test stimuli were stimuli 10 and 12, neither of which had been used during acquisition of matching. For the second and third pair of test stimuli, only one stimulus of the pair was novel, 9 in the second pair and 11 in the third pair.

During testing, food continued to be delivered for five correct consecutive matches. Fifty reinforcements per session were allowed. Errors of matching were followed by a 4-sec blackout as in acquisition and a resetting of the FR count. Transfer testing continued for nine sessions.

Posttest-1 phase. In order to compare the birds' matching performance of the stimuli used in Test 1, the stimulus pairs that were initially novel, but now familiar, were repeated, following the same order of the previous nine test sessions. Reinforcement and blackout contingencies remained in effect. This phase concluded when the ninth session following Test 1 was completed. Immediately following this phase, the birds were given a 30-day rest from the experimental procedures.

Pretest 2 phase. The birds were retrained to match with the same sets of stimulus pairs that had been used in the last two phases. Table 2 shows the stimuli used and their order of presentation for the remaining sessions of the experiment. After nine sessions of matching, the matching accuracy was demonstrated, and the birds were tested with symbolic-matching problems.

Testing for transfer. Test 2. The program was modified to present symbolic-matching problems involving four different stimuli. One of two stimuli was presented on the center key; two other stimuli appeared on the side keys. Selection of the center-key stimulus and determination of position for the side-key stimuli was made for each trial at random, using the tape reader and probability generator. Ten pecks to the center key produced the two stimuli on the side keys. A response to a side key showing a particular stimulus was designated a correct response and advanced the ratio count for reinforcement. Thus, correct responses were determined by the center-key stimulus and a peck on a particular side-key stimulus. For example, in Session 93 (see Table 2), pecks to the side key displaying a square (Stimulus 5) would be correct after pecking the center key illuminated with a red hue (Stimulus 4); responses to the other side key produced a blackout. In like manner, if the center key were showing a green hue (Stimulus 2), then pecks to the side key displaying a cross (Stimulus 8) would be correct and responses to the key with the square (Stimulus 5) would be in error. Control was evinced when the center-key stimuli were established as discriminative stimuli for pecking specific side-key stimuli. Five correct responses without errors were necessary before food was presented. An error produced a 4-sec blackout and reset the ratio count for reinforcement.

Different stimuli were presented in the second series of sessions. For the third series, the stimuli used in the second series were switched so that the side-key stimuli were now presented on the center key and the former center-key stimuli were displayed on the side keys. The first member of the stimulus pairs listed for Test 2 in Table 2 is the stimulus that could appear on the center key; the other stimuli were projected on the side keys. Stimuli used in the test phase were selected because the birds had successfully matched them in previous phases.

Posttest-2 phase. As a final assessment of matching accuracy, two more series of sessions were given that required matching-to-sample solutions. The experiment ended with the sixth Posttest-2 session.

RESULTS

In the course of 65 acquisition sessions, approximately 20,000 matching trials were presented in which eight novel stimuli were combined in 15 different ways. Figure 1 shows that

Table 2

Sequence of stimuli presented in Pretest-2, Test-2, and Posttest-2, with frequency of correct and incorrect responses for each pigeon.

Experimental Phase and Session Number	Stimulus Numbers	Bird					
		P1		*P2*		*P3*	
		Correct	*Errors*	*Correct*	*Errors*	*Correct*	*Errors*
PRETEST-2							
84	10, 12	373	78	285	35	288	40
85	10, 12	286	20	256	7	256	5
86	10, 12	267	10	275	13	254	1
87	5, 9	267	16	251	8	262	11
88	5, 9	259	10	254	2	259	7
89	5, 9	250	8	252	5	254	11
90	3, 11	254	10	250	0	255	12
91	3, 11	251	6	251	1	250	0
92	3, 11	253	2	250	1	254	5
TEST-2							
93	4-5, 2-8	540	247	660	336	542	228
94	4-5, 2-8	269	13	325	45	353	72
95	4-5, 2-8	280	24	272	13	302	75
96	10-7, 12-6	609	244	327	79	699	355
97	10-7, 12-6	356	67	269	27	288	34
98	10-7, 12-6	292	56	266	18	297	28
99	7-10, 6-12	460	146	505	242	452	175
100	7-10, 6-12	275	27	273	20	323	64
101	7-10, 6-12	289	37	259	14	273	44
POSTTEST-2							
102	5, 11	291	34	250	5	278	18
103	5, 11	259	15	262	10	259	20
104	5, 11	261	11	258	9	264	16
105	4, 8	281	26	253	4	250	2
106	4, 8	254	2	253	3	253	4
107	4, 8	252	3	250	2	250	3

in the initial series of sessions, matching performance developed in a fashion not uncommon to that reported elsewhere (Cumming and Berryman, 1961; Farthing and Opuda, 1974). Correct matches were made on about one half the trials, *i.e.*, at chance level during the first few sessions, then improving over the next sessions until a high proportion of responses were correct. All birds consistently matched with at least a 90% proficiency by the ninth session. Matching performance, however, deteriorated to near chance when, in the thirteenth session, a novel pair of stimuli was introduced. Six sessions later, all birds were matching these new stimuli with an accuracy near 90%. The introduction of a third pair of novel stimuli resulted in one bird, P3, matching close to a chance level, while the other birds, P1 and P2, matched at values well below chance. Again, all birds rapidly improved in performance over the next sessions. Disruption of matching reoccurred when the fourth set of novel stimuli was introduced, and to a lesser extent with the fifth pair of stimuli, both members of this pair having been presented before but not together. The introduction of the remaining 10 sets of stimuli produced less disturbance in the matching behavior of most birds. Familiarity with the individual stimuli might account for improved performance, since all eight stimuli used during the acquisition phase were presented in the first four series of sessions.

Figure 1 shows the transfer-of-matching data (Test 1) to two novel stimuli (Sessions 66 to 68) or one novel and one familiar stimuli (Sessions 69 to 71 and 72 to 74). When both stimuli were new to the birds, matching declined, but the reduction was not nearly as great as that observed when new sets of stimuli were introduced early in acquisition. When only one stimulus was new, matching

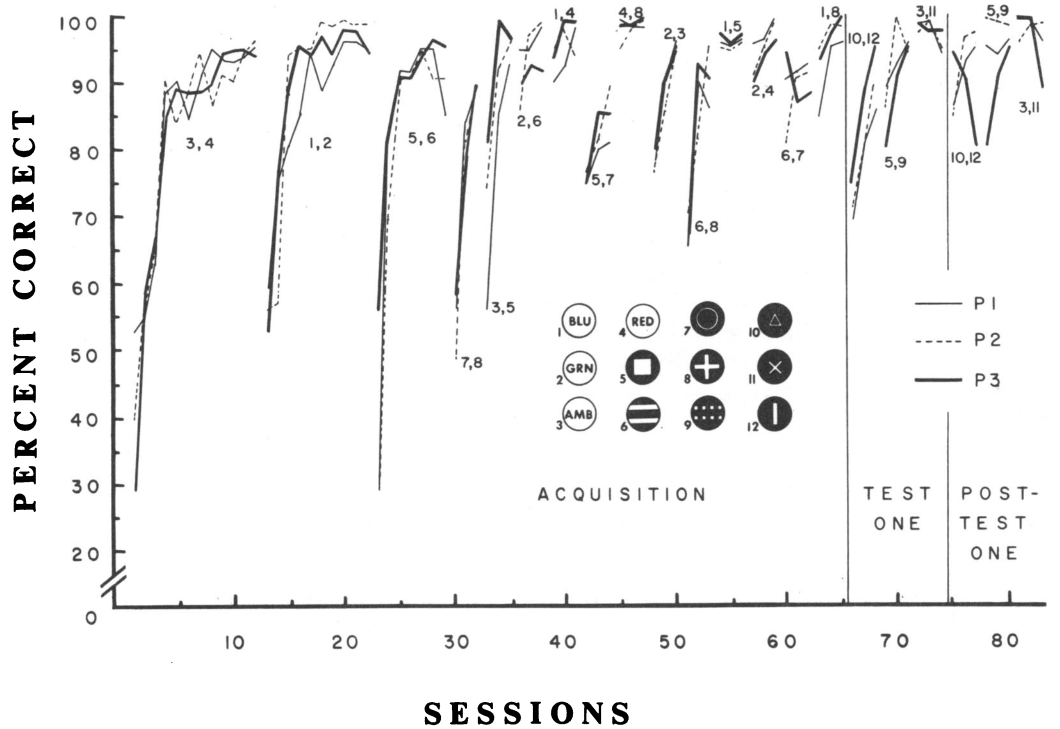

Fig. 1. Percentage of correct matching-to-sample responses for individual birds in 15 sessions of acquisition, nine transfer sessions, and nine sessions following transfer. The pair of numbers by each series of sessions indicates the stimuli used for that series (see stimulus-array insert).

performance remained at or above 80% correct. In the Posttest 1 repetition of the three series of transfer stimuli (Sessions 75 to 77, 78 to 80, and 81 to 83), a high percentage of correct matches continued. The slight improvement found in these series over the preceding three series might have been related to the improved familiarity of the once-novel stimuli and novel stimulus combinations.

The strongest evidence for positive transfer, however, would be shown if, at the introduction of novel stimuli, the birds showed no decline in matching behavior. Ideally, the substitution of novel stimuli should produce no detectable change in matching behavior or, at the least, matching performance in the first session of a series of sessions with the novel stimuli should not diminish. The performance in each initial session of a series in Figure 1 reveals any immediate effects of novel stimulus combinations. The proportion of correct matches for these sessions showed a gradual improvement as training progressed. The per cent of correct matches in the first sessions of a series in the transfer test approximated those percentages found in the initial sessions of the last 11 series in acquisition.

Evidence of positive transfer was less compelling, however, when the number of correct matches required to complete the first session of a series in Test 1 or the number of errors were considered. Table 1 shows that the number of matches of the first transfer session (Session 66), which involved two novel stimuli, was more than double that found for the 13 preceding sessions of acquisition for Bird P1, and nearly double for the other birds. When only one novel stimulus was introduced (Sessions 69 and 72), the increase in number of correct matches was reduced. Number of correct responses in the Posttest-1 sessions was near that obtained in the second and third transfer sessions of a stimulus series. The frequency of errors in the first transfer session was higher than the preceding 13 sessions. When compared to the last acquisition session in which two novel stimuli were used (Session 30), the incidence of errors in the first transfer session was less for Birds P2 and P3, but more for P1.

Figure 2 shows the per cent errors as a function of the ordinal count in the matching ratio. The per cent values were calculated by dividing the sum of errors at each stage in the count by the total number of opportunities to match at that stage. The opportunities to match at different stages varied, since any error occurring at a lower stage in the count automatically cancelled the opportunities to respond at higher stages. Two types of response preference were observed. Early in acquisition and occasionally later, birds would establish a position preference and repeatedly peck on one side key. The other type was to one of the side-key stimuli. Because of the correction procedure, if a response was incorrect the stimuli would not change until a correct match was made. All of these repeated errors after the first, however, would be included as Stage 1 errors, even though they comprised a distinct class of errors. Hence, calculations for per cent errors at Stage 1 in Figure 2 were adjusted to exclude any instance of repeated errors. The top panel of Figure 2 displays the location of errors in the ratio count for the last 36 sessions of acquisition. The proportion of errors was greatest in the early part of the FR count, declining and leveling off as the count proceeded. This finding was consistent with that of previously published reports of ratio reinforcement of matching behavior (Cumming and Berryman, 1965; Nevin, Cumming, and Berryman, 1963). The reports of these investigators, furthermore, showed that the decline holds for a variety of fixed ratios of matching. Their data, however, show a much steeper decline of errors for fixed ratios of 3, 6, and 10 than was now found.

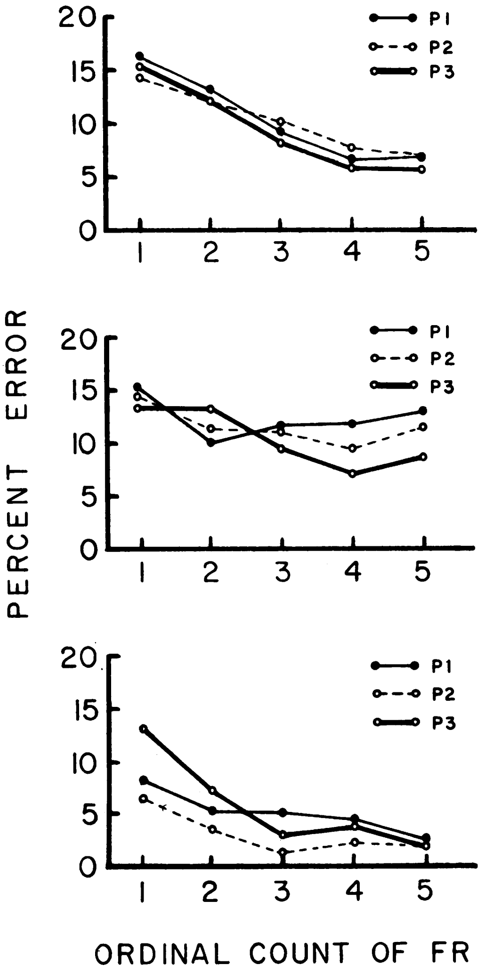

Fig. 2. Proportion of matching errors as a function of the progression of the FR count for the last 36 sessions of acquisition (top panel), the nine transfer-testing sessions of Test-1 (center panel), and the nine Posttest-1 sessions (lower panel).

The center panel of Figure 2 shows the per cent of errors for the nine transfer sessions of Test 1. The probability of errors declined as the count increased, but the decline was not as great or as consistent as that found during acquisition. Percentage of errors for the posttransfer sessions is plotted in the bottom panel. Again, the birds tended to make more errors early in the FR count. Table 3 provides a summary for the data shown in Figure 2 of the mean percentage of errors for the five levels of the FR count and the standard deviation of those percentages. The frequency distribution of errors in the FR count for individual birds during each phase is given in the Appendix.

Repeated errors to one side key (position preferences) have been detected in other studies of matching (Cumming and Berryman, 1961; Farthing and Opuda, 1974) and reportedly seemed especially strong before matching above the chance level and during the early development of matching behavior. In the present study, Bird P1 showed the greatest position preference. In six sessions of acquisition, this bird had 55% or more of its choice responses to one side (Sessions 2, 16, 23, 33, 42, and 48). Bird P2 showed position preference in Sessions 1 and 14, and P3 in three sessions (13, 14, and 15). No outstanding position preferences were found in transfer-testing or Posttest-1 sessions. The position-preference values (55% to 66%) observed for these birds are

Table 3

Mean Percentage of Errors per Level of the FR Count

	Bird					
	P1		*P2*		*P3*	
Experimental Phase	*Mean Percentage of Errors*	*Standard Deviation*	*Mean Percentage of Errors*	*Standard Deviation*	*Mean Percentage of Errors*	*Standard Deviation*
Acquisition (Last 36 sessions)	10.4	3.56	10.2	2.56	9.4	3.56
Test-1	12.4	1.62	11.7	1.81	10.2	2.61
Posttest-1	5.2	1.43	3.3	1.75	6.1	4.16
Pretest-2	5.2	1.93	2.4	1.02	3.2	2.81
Test-2	17.0	0.57	16.0	2.02	19.9	1.03
Posttest-2	4.0	2.27	1.7	2.38	3.1	2.53

much less than the values (67% to 87%) reported by Farthing and Opuda (1974). The correction procedure used in the present study probably accounts for the difference, since this procedure extinguished any position habit. Analysis of the frequency of repeated errors to one or the other comparison stimuli without regard for position showed no consistent discernible difference between sessions and across birds for the last 11 series of acquisition sessions, the sessions of Test-1, or the Posttest-1 sessions. The Appendix shows the sum of repeat errors for individual birds.

Data from the Posttest-1 sessions show that matching performance to the transfer stimuli could be obtained at 90% correct or better. One bird, P3, displayed a rather unusual high error rate in Session 77.

Before the next phase began, the birds were absent from matching practice for 30 days, yet when returned to the experiment in the Pretest-2 phase only a slight decrement in matching performance was observed. Correct matching of familiar stimuli in the first session occurred on more than 80% of the trials. Pigeon P1 made about twice as many errors as the other birds. Frequency of correct responses and errors appear in Table 2.

Figure 3 shows performance in the last three phases. Correct matching during Pretest-2 and Posttest-2 is consistently high. Correct responding in the test period, while less than that found in the other phases, was nevertheless near 70% initially in every series and 85% to 90% in the later sessions of each series.

The distribution of errors in the FR count is plotted in Figure 4 for the last three phases. As done with the data-point calculations of Figure 2, repeated errors were not included. The figure shows that the proportion of errors was slightly higher at the beginning of the count for the Pretest-2 and Posttest-2 periods. In the Test-2 phase, the per cent error is greater than in the other phases, and the errors tend to be distributed evenly throughout the count levels. The second half of Table 3 gives the means and standard deviations of the percentage of errors at the five levels of the FR count.

Comparison of the absolute number of errors (Table 2) made in Pretest-2 and Posttest-2 sessions with those sessions of Test -2 showed substantial differences. Furthermore, the incidence of errors in the Test-2 phase is much

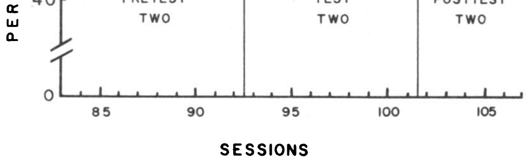

Fig. 3. Percentage of correct responses for problems solved by matching to sample. (Pretest-2 and Posttest-2 sessions) and for problems solved by symbolic matching (Test-2 sessions). The numbers by each series of sessions indicate the stimuli used for that series (see stimulus-array insert). In Test 2, the first member of the two pairs of stimuli could be the standard stimulus; the others were the comparison stimuli.

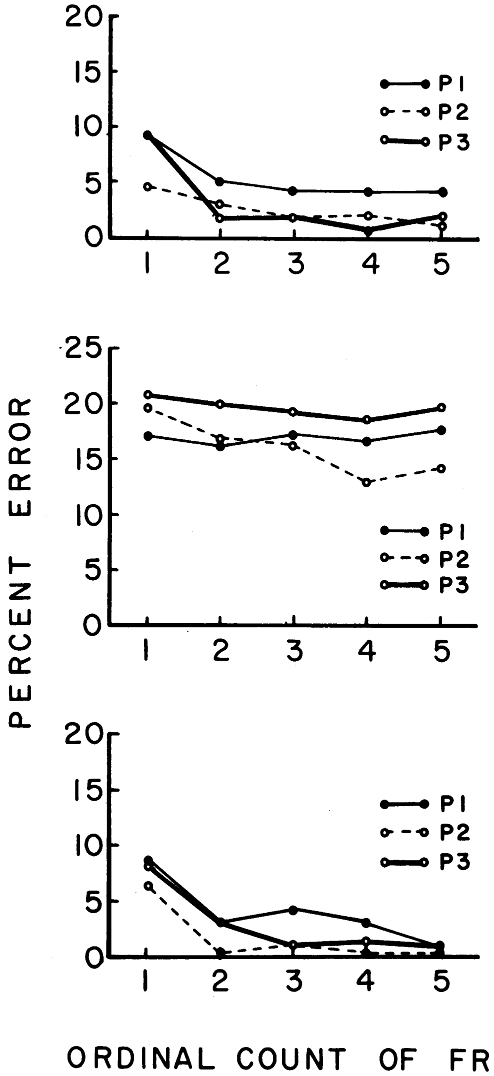

Fig. 4. Proportion of response errors as a function of the progression of the FR count for the last three experimental phases: Pretest-2 (top panel), Test-2 (center panel), and Posttest-2 (lower panel).

higher than that of comparable sessions for the phases immediately preceding and following.

Finally, the data for the last three phases showed no indication of position preferences or a consistent relationship between the proportion of repeat errors and the different phases.

DISCUSSION

The purpose of the first test was to determine if transfer of matching behavior could be enhanced by reducing any disruptive effects resulting from the mere presentation of novel stimuli. Successful transfer might indicate that pigeons develop a matching concept (*cf.* Farthing and Opuda, 1974). Such an hypothesis is attractive, straightforward, and uncomplicated, but the evidence collected in Test-1 supporting this hypothesis is, at best, weak. After 65 training sessions with 15 different problems, all birds showed excellent mastery of matching. When presented with a transfer problem with novel stimuli, their correct matching performance did approach 70% to 75% correct. This finding is counter to that reported by Farthing and Opuda (1974), who observed that their birds matched only about 30% correct in a transfer situation that involved similar novel stimuli. The difference in values might be related to differences in training or to a number of other procedural differences, but is most likely a function of the different session lengths employed. Farthing and Opuda used a fixed number of trials (120 per session); in the present study, the number of trials depended on matching accuracy. The other supportive evidence was a reduction in the frequency of errors by two birds made in the first transfer session, as compared to the number of errors made in an earlier acquisition session that also used two novel stimuli. It could be argued that fewer errors were made in the later session because the matching concept was more firmly established. Yet, the frequency of errors in this transfer session was considerably higher than the birds' usual error count found in the later sessions of acquisition training (compare birds' frequency of errors for Session 66 with that of Sessions 54, 57, 60, and 63 in Table 1).

The results from the second transfer test make the matching-concept hypothesis even more questionable. The birds that had been extensively trained on matching problems, and that had achieved a high percentage of correct matching, were given problems that involved symbolic matching. Results showed a high per cent correct responding to these problems in spite of the fact that each problem employed more stimuli than the matching problems used for training. If the birds did indeed respond on the basis of a matching concept, then it might be expected that the extensive training would have little effect on (or perhaps even impair) the birds' performance on this new problem.

Yet, the obtained values for correct responding were well above chance levels. Since the nature of the test problems required solutions based on specific stimulus-response chains, the data support an hypothesis of stimulus-response chaining, rather than a matching concept. It is reasonable to expect that the positive transfer observed might be, in part, related to a general attentional factor that develops with practice. Such a factor could increase the chance that a relationship between the standard stimulus and the comparison stimuli would more readily be established by the birds and, thus, facilitate a stimulus-response chaining solution.

The form of the distribution of errors during the FR was surprising. Nevin *et al.* (1963) examined various ratio schedules of matching behavior, including FR 6, and related matching accuracy to the ordinal number of the trial since reinforcement. Their findings for the FR 6 schedule showed an unusually high proportion of errors for the trial immediately following reinforcement (more than 40% errors for two pigeons and about 35% for another bird) and a marked improvement in accuracy developing over the next four to five trials that followed reinforcement. A similar trend was apparent for other fixed-ratio values (FR 3 and FR 10), but not for a variable-ratio schedule (VR 3). The percentage of errors for the VR 3 schedule of matching was low and essentially constant for all levels of the ratio count. This flat function of the VR 3 schedule is quite like that observed in all phases of this experiment (Figures 2 and 4), except for the acquisition phase (Figure 2, top panel), which showed a more pronounced percentage of errors for the first trial after reinforcement. The earlier data, however, were taken during a period long after their birds had acquired matching accuracies of 96% to 98%. Thus, comparison of the data for matching acquisition may be questionable. The difference in findings between that of Nevin *et al.* and the present study might lie in the type of fixed-ratio schedule requirements now imposed. That is, in the present experiment, the fixed ratio had to be completed without error before food was presented. A bird making errors during a session had the effect of producing a ratio schedule with various response requirements, but with a minimum requirement of five correct responses in succession. As performance improved, the ratio became less varied, until the FR 5 was realized and matching accuracy was near maximum.

Farthing and Opuda (1974) reported excessive responses to the standard stimulus, *i.e.*, continued pecking to the center key even after the side keys had been illuminated. These pecks, which had no scheduled consequence, were a function of the stimulus dimensions tested (hues and geometric forms) and varied nonlinearly with the stage of training. They were interpreted as related to the birds' receptor-orienting response (or observing response). In the present experiment, no notable excessive pecking to the standard stimulus was detected, although an occasional session occurred with a few (fewer than five) unnecessary center-key pecks. The observing-response requirement used in this study, 10 pecks to the center key, differed from the former study,

Appendix

Frequency distribution of errors for the stages of the fixed-ratio ordinal count and sum of repeated errors. Values for Stage 1 exclude occurrences of repeated errors.

	Stage of FR Count					*Repeat Errors*
	1	*2*	*3*	*4*	*5*	
ACQUISITION (SESSIONS 30-65)						
P1	500	337	219	149	138	542
P2	428	314	236	166	140	396
P3	453	310	183	129	112	322
TEST-1 (SESSIONS 66-74)						
P1	135	72	78	73	69	114
P2	123	82	74	50	59	73
P3	103	89	51	39	41	43
POSTTEST-1 (SESSIONS 75-83)						
P1	47	27	26	22	15	14
P2	36	15	8	12	11	20
P3	85	39	15	19	12	76
PRETEST-2 (SESSIONS 84-92)						
P1	55	24	20	20	19	22
P2	22	16	10	7	5	12
P3	46	9	8	6	9	14
TEST-2 (SESSIONS 93-101)						
P1	194	153	139	108	97	170
P2	206	147	120	79	74	168
P3	290	206	161	125	107	186
POSTTEST-2 (SESSIONS 102-107)						
P1	31	11	13	8	8	20
P2	21	1	4	0	1	6
P3	28	10	4	6	4	11

which required only one peck, and seemed adequate for maintaining the necessary observing response. Other experiments have shown that more than one required response to the standard stimulus yields accelerated acquisition and improved accuracy with zero-delay matching-to-sample problems (Sachs, Kamil, and Mack, 1972) and oddity-matching problems (Lydersen, Perkins, and Chairez, 1977).

In conclusion, the present data, when considered with the findings of earlier research (Cumming and Berryman, 1961; Cumming *et al.*, 1965; Farthing and Opuda, 1974) may be taken to support the stimulus-response chaining hypothesis. At this time, it seems that the appraisal offered by Farthing and Opuda (1974) is still justified. It appears unlikely that pigeons normally use a matching concept as the basis for their responding in a matching-to-sample situation.

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