TRANSFER OF MATCHING-TO-FIGURE SAMPLES IN THE PIGEON

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Three pigeons were trained on a modified six-key matching-to-sample procedure. The third peck on the figure-sample key (which presented a bird, hand, face, beetle, rabbit, fish, flower, or red hue, as the sample) lighted only one comparison key. Every three additional pecks on the sample lighted another comparison key, up to a maximum of five keys. Pecks on keys of matching figures produced grain. Pecks on nonmatching keys (mismatches) turned off all lights on the comparison keys and repeated the trial. Three figures were used during acquisition. The birds learned to peck each sample until the matching comparison stimulus appeared on one of three comparison stimulus keys, and then to peck that key. Later, five novel stimuli, employed as both sample and comparison stimuli, and two additional matching keys were added. Each bird showed matching transfer to the novel samples. The data suggest that the birds may have learned the concept of figure matching rather than a series of two-component chains or discrete five-key discriminations.

Key words: matching to sample, conditional discriminations, transfer, concept of matching, key pecks, pigeons

It has often been suggested that conditional discrimination procedures can provide assessments of conceptual learning ability in nonhumans. Conceptual or rule-governed behavior is evidenced by either above-chance performance with novel stimuli, or at least rapid acquisition when confronted with novel problems of conditional discrimination. For this purpose, among others, the matching-to-sample (MTS) procedure has frequently been employed (e.g., Cumming & Berryman, 1965; D'Amato, 1973; Grant & Roberts, 1976; Honig, 1978; Wright & Sands, 1981). Three explanations for maintained matching behavior have been suggested (Carter & Werner, 1978; Farthing & Opuda, 1974). They include: (1) the "single-rule model," which claims that animals learn

a matching concept; (2) the "multiple-rule model," which proposes that animals learn a set of "if-then" rules—that is, nonhumans acquire a set of two component chains; and (3) "the configuration model," which suggests that animals learn a group of three-key discriminations. Some evidence of "single-rule" behavior has been reported in monkeys (Fujita, 1982, 1983; Mishkin, Prockop, & Rosvold, 1962), apes (Nissen, Blum, & Blum, 1948), and dolphins (Herman & Gordon, 1974). It should be noted that in this context "rule" designates a behavior-environment relationship, and does not imply a separate description or formal discriminandum as basis for that relationship.

Several papers have attempted to ascertain the precise nature of the behavior-environment relationship when pigeons acquire conditional discriminations. Numerous reports have cited little or no initial transfer of matching to novel samples (e.g., Carter & Werner, 1978; Cumming & Berryman, 1961; Farthing & Opuda, 1974). The evidence appears to support the response-chains position (e.g., Carter & Eckerman,

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1976; Cumming, Berryman, & Cohen, 1965; Farthing & Opuda, 1974; Holmes, 1979; Premack, 1978).

Some researchers have attempted to demonstrate concept learning in pigeons by using variations of the MTS paradigm. For example, Malott and Malott (1970) trained birds to peck a key if both halves of the key were transilluminated with the same hue. Extinction was in effect if the key showed two different hues. After acquisition, the birds showed transfer with novel hues. In a related study, Honig (1965) demonstrated that pigeons could learn to peck one of two lighted keys if both keys showed the same stimulus, and to peck the other key if the keys were presenting different stimuli. The birds also showed transfer to novel stimuli. Fujita (1983) trained monkeys to lever press when two keys showed the same color, red or purple, and to refrain from lever pressing when the stimuli did not match (i.e., a red-purple stimulus presentation). Three of the four monkeys showed transfer to novel stimuli, yellow-green and blue-green.

Urcuioli and Nevin (1975) suggested that pigeons may not show MTS transfer because they learn a set of " S^D rules" (i.e., if red on the center, peck red on the side key), but not a set of S^A rules (i.e., not to peck non-matching comparison stimuli). Their procedure presented a red, green, or yellow sample on the center key. A response on the sample lighted only one of the comparison-stimulus keys. If the comparison stimulus matched the sample, and the bird pecked it, a reinforcer was delivered. If the comparison stimulus did not match the sample, it was terminated and the matching hue was presented on the alternate side key after 4.8 s, provided the bird did not peck the non-matching hue. Pecks on the nonmatching hue reset the 4.8-s interval. The birds produced shorter latencies with matching hues relative to those for nonmatching hues. Transfer to novel hues (blue and violet) was obtained. The authors suggested that for pigeons, when S^A as well as S^D relationships are emphasized by the procedure, transfer of matching can occur (i.e., concept

matching). Urcuioli (1977) used the same procedure to demonstrate transfer of oddity-from-sample (OFS) matching. In two related papers, Zentall and Hogan (1978), and Zentall, Hogan, and Edwards (1980) trained birds on both the MTS and OFS tasks. Some birds were exposed to negative instances—trials with two incorrect comparison stimuli. Birds trained with negative instances produced higher matching accuracies and produced better transfer to novel samples than did control birds that received only standard MTS and OFS training.

Malott and Malott (1970) measured differences in response rates, whereas Urcuioli and Nevin (1975) and Urcuioli (1977) reported latency data. The typical MTS experiment, however, usually presents about 96 trials and reports the percentage of the trials on which the birds made no errors. The present study combined elements of the Urcuioli and Nevin (1975) procedure with conventional MTS contingencies. The pigeon was presented with a sample stimulus. Three pecks on the sample produced a comparison stimulus. Every three additional pecks on the sample produced another comparison stimulus, up to a maximum of five. The bird's task was to peck the sample key until the matching comparison stimulus appeared; then a peck on the matching comparison stimulus produced a reinforcer. As in other MTS experiments, the percentage of correct matches was the primary indication of matching acquisition and of transfer of matching to novel stimuli.

Figures were used as stimuli instead of hues or forms, in order to reduce the likelihood of transfer by stimulus generalization. Several researchers have indicated that pigeons can discriminate between complex visual stimuli. Herrnstein (1979), and Herrnstein, Loveland, and Cable (1976) demonstrated that pigeons can discriminate between pictures of trees, water, and particular people. Pigeons can also discriminate between symmetrical and nonsymmetrical forms (Delius & Habers, 1978; Delius & Nowak, 1982). Blough (1982) used letters of the alphabet as S^D s. These researchers

employed the stimuli in go/no-go discriminations with reinforcers produced by responses on S^D stimuli. The present study used complex figure stimuli (e.g., a face, a hand) in a conditional-discrimination procedure. With five comparison keys, seven complex figure stimuli, and 30 different spatial arrays available, it seemed that acquisition of matching and rapid transfer to novel stimuli could be considered as evidence of conceptual learning. Furthermore, the data could not be easily interpreted in terms of either the response chains or sets of conditional discriminations (#2 and #3) cited earlier.

METHOD

Subjects

Three White Carneaux pigeons, maintained at $80\% \pm 15$ g of their free-feeding weights, were used. The pigeons had been previously used in an autoshaping experiment (Pisacreta, Redwood, & Witt, 1983) but had not been exposed to the stimuli used in the present study.

Apparatus

The apparatus was a 35 by 35 by 37-cm operant chamber enclosed in a sound-attenuating hull. Figure 1 shows the response panel; its dimensions were 37 cm by 35 cm; it had eleven 2.7-cm response keys (BRS/LVE Model #121-16). Stimuli were rear projected onto the keys by means of Industrial Electronics Engineers inline projectors (Model #1813-1820). The operating force of each key was approximately 0.16 N. The horizontal and vertical distances between the keys were 8.1 and 6.4 cm, respectively, center to center. A 6 x 6-cm feeder aperture was centered on the wall 10 cm above the floor.

The feeder (BRS/LVE Model #114-10) provided 3-s access to grain. The houselight ("h" in Figure 1), a GE #1820 lamp, provided light before and after daily experimental sessions. During sessions, illumination was provided only by the inline projectors. Response Keys 7, 8, 9, 10, and 11 were

Fig. 1. The response panel: The pecking keys are numbered 1 through 11. H and SA represent the houselight and sonalert; SP is the speaker that provided masking noise.

never illuminated. A ventilation fan and white noise delivered through the speaker masked extraneous noise. An E and L Instruments MMD-1 computer and additional hardware recorded data and controlled experimental events.

Figure 2 shows the stimuli that were employed; these stimuli were selected from Harter (1978). In addition to the eight black-and-white stimuli, the four remaining positions of the inline projectors allowed hues (red, blue, green, or white) to be presented.

Procedure

Table 1 summarizes the experiment.

Phase 1: Acquisition. The birds were initially trained to match three stimuli—the woman, the bird, and the hand. At trial onset Key 5 (the sample key) presented one of these stimuli, chosen in random order. A peck on the sample key illuminated Key 1 with a comparison stimulus. A second peck on the sample key lighted Key 3 with the second comparison stimulus. Additional pecks on Key 5 had no programmed consequence. The bird's task was to peck the sample key

Fig. 2. The figure stimuli presented as samples and matching stimuli. The four blanks could project red, blue, green, or white hues onto the key.

Table 1
Summary of Conditions

Phase	Comparison Keys and Sequence	Stimuli Available*	Sample Ratio	Sessions
1	1,3	W,B,H	1	1-25
1	1,3	W,B,H	2	26-50
1	1,3	W,B,H	3	51-75
1	1,3	25/30 Trials = Key 3 Matches	3	76-100
1	1,3	W,B,H	3	101-125
2	1,2,3	W,B,H	3	50
3	1,2,3	W,B,H,Be	3	25
4	4,1,2,3	W,B,H,Be	3	35
5	4,1,2,3	W,B,H,Be,FL	3	30
6	6,4,1,2,3	W,B,H,Be,FL	3	35
7	6,4,1,2,3	W,B,H,Be,FL,F	3	25
8	6,4,1,2,3	W,B,H,Be,FL,F,RA	3	15
9	6,4,1,2,3	W,B,H,Be,FL,F,RA,Red	3	15
10	6,4,1,2,3	W,B,H,Be,FL,F,RA,Red Zero-Delay Matching	3	25

*The stimuli included the (W)oman, (B)ird, (H)and, (Be)tle, (FL)ower, (F)ish, (RA)abbit, and Red.

until the matching comparison stimulus appeared on Key 1 or Key 3. A peck on the matching comparison stimulus produced a reinforcer, a 3-s intertrial interval, and the next trial. An incorrect response—a peck on the nonmatching comparison stimulus—eliminated the comparison stimuli and repeated the same trial. This “correction procedure,” presenting the same sample and sequence of comparison stimuli, was in effect throughout the experiment. Sessions ended after 30 reinforcers (successful matches). These conditions lasted 25 sessions. During the next 25 sessions two pecks on the sample key (a fixed ratio 2, FR 2 schedule) were required before a comparison stimulus was provided. Thus, two pecks on Key 5 illuminated Key 1 and two additional pecks to the sample lighted Key 3 with the second comparison stimulus. The requirement was raised to FR 3 during the next 25 sessions.

In Sessions 76 through 100 we attempted to reduce a Key 1 preference by providing the matching comparison stimulus on Key 3 during 25 of the 30 reinforced trials. During Sessions 101 through 125 the correct matching comparison stimulus appeared equally often on Keys 1 and 3. The birds were trained daily for two or three consecutive sessions per day (60 to 90 reinforced trials) during the entire experiment. Comparing the first and last session of the day provided evidence of any warmup or satiation effects.

Phase 2: Three comparison stimuli. The FR 3 sample requirement was in effect for the rest of the experiment. Three pecks on the sample illuminated Key 1 as before. Three additional pecks lighted Key 2 with the second comparison stimulus. Three more pecks produced the third comparison stimulus on Key 3. Additional pecks on the sample key had no consequence. Therefore, each session provided the woman, bird, and hand as samples and each stimulus was potentially available as a comparison stimulus during each trial.

Phase 3: Novel beetle. A novel stimulus refers to a figure stimulus that had not been presented during previous phases. During the next 25 sessions the beetle was randomly

presented as the sample during a minimum of 9 of the 30 reinforced trials in each session. It was also presented as an incorrect comparison stimulus during a minimum of six trials in each session.

Phase 4: Four comparison stimuli. Key 4 was introduced as a comparison-stimulus key. Pecks on the sample (viz., 3, 6, 9, or 12 pecks) produced comparison stimuli on Keys 4, 1, 2, and 3, in that order. Consequently, the beetle was potentially available as a comparison stimulus during each trial. Phase 4 lasted 35 sessions.

Phase 5: Novel flower. During the next 30 sessions the flower was randomly presented as a sample stimulus during a minimum of six trials, and as a nonmatching comparison stimulus during a minimum of 12 trials.

Phase 6: Five comparison stimuli. Key 6 was available as a comparison stimulus key. Pecks on the sample key (viz., 3, 6, 9, 12, or 15 pecks) sequentially produced comparison stimuli on Keys 6, 4, 1, 2, and 3, in that order. Phase 6 lasted 35 sessions.

Phases 7, 8, and 9: Additional novel stimuli. Phase 7 (25 sessions) employed six stimuli—the five figures used before and the fish. The fish served as the sample during at least six randomly chosen reinforced trials, and as a nonmatching comparison stimulus during a minimum of 10 trials. Phase 8 (15 sessions) randomly presented the rabbit as a sample during six reinforced trials, and as a nonmatching comparison stimulus during at least five trials. The other six stimuli served as samples at least four times during each session. Phase 9 introduced red as a sample (six reinforced trials per session) and as a nonmatching comparison (at least five trials per session) during each of the 15 sessions of this phase. Therefore, each trial could provide five of the eight randomly chosen stimuli.

Phase 10: Zero-delay matching. The first nine phases were examples of simultaneous matching. The sample was present when the bird pecked a comparison stimulus. The 25 sessions of the tenth phase employed the same eight stimuli and five comparison keys as Phase 9, but the sample was absent when

the bird pecked a comparison stimulus. At trial onset Key 5 presented white light. Each peck on Key 5 replaced white with the sample stimulus, but only for as long as the key was depressed; the sample stimulus was replaced with white light after each peck. Thus, the sample was absent when the bird pecked a comparison stimulus.

RESULTS

The data of interest include matching accuracies, and error distributions as functions of comparison stimuli, comparison stimuli key presentation order, and novel stimuli. Figure 3 shows the percentage of trials in which each bird pecked only the matching comparison stimuli during Phase 1.

The first panel shows that each bird matched correctly during approximately 50% of the trials, which constitutes performance at the level of chance, when only a single response was required to produce each successive sample. The birds frequently

pecked the sample, then Key 1. If Key 1 was incorrect, they pecked the sample twice and then pecked Key 3. Hence, they maintained 50% (chance) matching accuracies. These position preferences are not uncommon during initial training with matching tasks (e.g., Carter & Werner, 1978; Cumming & Berryman, 1961). Raising the sample ratio to FR 2 and FR 3 produced matching improvement only in Bird B1, as shown in the second and third panels of the figure. Scheduling the correct matching comparison stimulus on Key 3 during 83% of the trials (Panel 4 of the figure) produced improved performances while it was in effect, but it did not yield permanent matching improvement in performances of Subjects B2 and B3, as shown in the fifth panel.

Figure 4 shows the matching accuracies maintained during the next four phases. Introducing the third comparison key systematically improved matching in Subjects B2 and B3, although chance performance was now reduced to 33% as compared to 50%

Fig. 3. The percentage of trials during Phase 1 in which the first peck on a comparison stimulus was a match, for each of the three pigeons. Each data point represents a mean taken over two consecutive sessions, except (*), which represents a single session. Chance performance equaled 50%.

Fig. 4. Matching accuracies produced during Phases 2 through 5. Each data point represents a mean taken over two consecutive sessions, except those identified by (*), which denotes single sessions. The number above each panel identifies the phase. Chance performance was 33% during Phases 2 and 3, and 25% during Phases 4 and 5.

during Phase 1. By the end of Phase 2, Birds B1, B2, and B3 were matching without error on 96%, 80%, and 62% of the trials, respectively. No sample produced significantly more errors than the others. Similarly, errors on the comparison stimuli were comparable.

Introduction of the novel beetle stimulus (Phase 3) yielded initial matching decrements. The birds did not avoid the novel beetle comparison stimulus; Birds B1, B2, and B3 emitted 34%, 16%, and 17% of their errors, respectively, in pecking the beetle key. Introducing the fourth comparison stimulus key in Phase 4 also initially reduced matching levels. By the end of the phase, the matching accuracies of each bird were comparable to those maintained in Phase 2, although chance matching performance was now 25%. Introduction of the flower in Phase 5 produced initial matching deficits in all birds with a gradual recovery (within four

to ten sessions) to Phase 4 matching levels. Birds B1, B2, and B3 produced 27%, 30%, and 30% of their errors by pecking the flower comparison stimulus.

Figure 5 presents the accuracies of matching that occurred during the last five phases of the study. With five comparison keys available, chance matching accuracy was 20% during each phase. As had occurred in Phases 2 and 4, introducing an additional comparison key in Phase 6 produced initial decreases in accuracy of matching, followed by gradual recovery. A comparison of terminal performances in Figure 4 (Phases 4 and 5) with Phase 6 reveals that each bird eventually produced matching levels with five comparison stimuli roughly comparable to those matching accuracies maintained with four comparison keys (B1 was a bit lower, B3 a bit higher). Pigeons B1 and B2 produced 80% matching accuracies, with their first peck to a comparison stimulus

Fig. 5. Matching accuracies produced during Phases 6 through 10. Each data point represents a mean taken over two consecutive sessions, except (*), which denotes single sessions. Chance performance was 20% across these phases.

being a correct match during 24 of the 30 trials. Similar to the earlier phases, no particular sample or comparison stimulus occasioned a statistically significant number of errors relative to any other stimulus.

Presenting three additional stimuli (Phases 7, 8, and 9) yielded 10% to 40% matching accuracy reductions followed by matching recovery within a few sessions. Finally, during Phase 10 each bird maintained above-chance matching accuracies with the zero-delay matching condition.

Figure 6 displays the distribution of comparison stimulus errors across the keys during various phases. The numbers above each panel represent a percentage of errors-per-opportunity (err/op) analysis—that is, key errors divided by the number of times a given key was lighted with an incorrect comparison stimulus. The figure shows that in the first three conditions of Phase 1, each

bird made the majority of its errors on comparison Key 1. Mean errors per session on Keys 1 and 3 were 13 and 3, respectively (group data). Presenting the matching comparison stimulus on Key 3 during the majority of the trials (fourth panel) altered the error distributions of only Subject B1. Panel 6 (Phase 2) shows that the highest percentage of errors and err/op occurred on Key 2, and the fewest errors made by each bird were on Key 3. Mean errors per session on Keys 1, 2, and 3 were 10, 15, and 3, respectively (group data). During Phases 4 and 6, errors generally decreased with each consecutive comparison-stimulus key presentation. During Phase 4 mean errors per session on Keys 4, 1, 2, and 3 were 12, 4, 2, and 2, respectively. Similarly, during Phase 6 mean errors on Keys 6, 4, 1, 2, and 3 were 10, 4, 3, 3, and 2, respectively.

During the acquisition sessions of Phases

Fig. 6. The black bars represent the percentage of errors (including correction trials) across comparison keys during various phases. The comparison key orders on the abscissae represent the order in which sample pecks produced them. The number above each bar represents the percentage of errors emitted per opportunity, viz., the number of errors made on a key divided by the number of times the key was lighted with an incorrect comparison stimulus.

2, 4, and 6 (three-, four-, and five-key matching), the birds tended to peck either the first comparison stimulus that appeared or the comparison key that was correct during the previous trial. During the first three sessions of Phase 2 the birds made 51%, 39%, and 10% of their errors on Keys 1, 2, and 3, respectively (group data). During the first three sessions of Phase 4, 68%, 7%, 9%, and 16% of the errors were made on Keys 4, 1, 2, and 3, respectively. Similarly, during the first three sessions of Phase 6, the birds emitted 28%, 25%, 24%, 15%, and 8% of their errors on Keys 6, 4, 1, 2, and 3, respectively. After matching accuracies improved, the birds pecked the sample and momentarily paused each time another comparison stimulus was produced. They seldom produced all the available comparison stimuli before pecking a comparison stimulus. Essentially, they pecked the sample, paused while looking at each additional com-

parison stimulus, and frequently shifted to the matching comparison stimulus as soon as it was available. The error and err/op distributions generated in Phases 7 through 10 were similar to those produced in Phase 6.

Figure 7 shows error distributions as a function of the key on which the matching comparison stimulus was presented. The first two panels, Phases 2 and 3, show that each bird made the highest percentage of errors when Key 3 (the last key to light) was programmed to present the matching comparison stimulus. Introducing the fourth and fifth comparison keys in Phases 4 and 5, respectively, yielded similar trends; that is, errors tended to increase with the number of comparison keys that had to be lighted before the matching comparison stimulus was presented. The majority of these errors were produced during the first few sessions of each phase, as illustrated in Table 2.

Table 2
Initial transition errors across phases. Data show the mean errors made on comparison stimuli during the last three sessions of a phase, and during the first three sessions of the subsequent phase. The comparison stimuli included: (H)and, (B)ird, (RA)bbit, and RD (red hue). Ss = subjects, nov = novel stimulus.

Phase 1 to Phase 2						Phase 2 to Phase 3						Phase 3 to Phase 4													
2-choice						3-choice				nov-beetle						4-choice									
Ss	H	B	W		H	B	W		H	B	W	Be		H	B	W	Be	H	B	W	Be				
1	1	1	0		23	15	21		0	0	0		4	7	3	2		1	1	1	1	8	9	7	5
2	5	5	0		23	32	10		1	1	1		10	7	14	1		1	1	1	3	12	16	15	14
3	6	6	5		35	54	36		5	4	3		8	7	7	2		4	4	4	3	15	18	10	14

Phase 4 to Phase 5										Phase 5 to Phase 6												
					nov-flower										5-choice							
Ss	H	B	W	Be		H	B	W	Be	FL		H	B	W	Be	FL		H	B	W	Be	FL
1	1	0	0	2		8	6	2	7	3		0	0	0	0	0		7	5	3	1	10
2	3	0	0	4		12	13	12	6	2		4	1	1	1	3		10	6	13	4	15
3	4	4	3	7		24	15	11	6	8		2	3	4	2	3		11	24	33	19	30

Phase 6 to Phase 7										Phase 7 to Phase 8																	
					nov-fish										nov-rabbit												
Ss	H	B	W	Be	FL		H	B	W	Be	FL	F		H	B	W	Be	FL	F	RA							
1	1	3	2	2	2		1	1	2	1	2	2		1	1	2	1	2	2		3	3	5	0	14	5	6
2	1	1	1	2	2		5	4	7	4	10	0		0	0	1	1	1	2		4	4	7	3	15	5	3
3	3	4	1	2	3		5	3	1	1	9	2		1	3	2	1	0	3		6	10	14	7	17	6	11

Phase 8 to Phase 9										nov-red									
Ss	H	B	W	Be	FL	F	RA			H	B	W	Be	FL	F	RA	RD		
	1	0	0	2	0	0	1	1			3	8	1	2	2	2	20	2	
	2	1	3	1	2	2	1	3			15	10	4	2	2	12	1	1	
	3	1	2	2	2	3	2	2			27	37	3	7	17	40	9	0	

Phase 9 to Phase 10										0 delay									
Ss	H	B	W	Be	FL	F	RA	RD		H	B	W	Be	FL	F	RA	RD		
	1	0	1	1	0	1	0	0	3		4	3	4	0	7	4	2	10	
	2	0	0	0	0	1	0	1	0		12	4	3	3	6	5	7	15	
	3	1	1	2	1	1	2	1	1		8	6	3	1	2	4	2	3	

Table 2 presents a comparison of errors produced during the last three sessions of each phase with errors made during the first three sessions of the subsequent phase. In general, the data reveal that (1) errors were fairly equally distributed across all comparison stimuli, (2) novel stimuli were not initially avoided, (3) introduction of novel stimuli initially increased errors on all comparison stimuli, and (4) several phases (2-3, 6-7, 7-8) produced only small increases in errors. As reflected in earlier figures, Birds B1 and B2 reliably performed better than Pigeon B3. After the initial increase in

Fig. 7. Error distributions (including repeated trials) as a function of correct comparison key. The numbers below each panel indicate the correct comparison key to peck, as well as the order in which sample pecks produced them. The numbers above each panel represent phases of the experiment. For example, during Phase 2 subject B1 made 1, 22, and 77% of its errors when the correct key to peck was comparison Key 1, 2, and 3, respectively.

errors, each birds reduced its errors within five to ten sessions to those levels observed at the end of the previous phase.

Figure 8 shows the errors emitted during the trials in which a novel stimulus served as the sample. For example, each data point of Panel 1 shows the mean number of errors (mismatches) that each bird made during two consecutive sessions while matching the beetle 18 times (nine times per session). Panel 1, data from Phase 3, shows that each bird made few errors while learning to match the beetle. Bird B1 made fewer than five errors after the first 18 trials with the beetle presented as the sample. Pigeon B3 made fewer than 18 errors per session throughout Phase 3. Each successive panel shows an initial increase in errors followed by matching acquisition within 6 to 10 sessions. Phase 7 offered five comparison stimuli, so 3 to 15 sample key pecks were required before the matching novel fish com-

parison stimulus appeared. Even so, Birds B1 and B3 averaged fewer than ten errors per session from phase onset. Comparable results were produced during Phase 8, which introduced the rabbit. Curiously, introducing a homogeneous field (the red hue) yielded the highest number of errors in Birds B2 and B3, although the hue was presumably a simpler stimulus to discriminate than the figure stimuli. Similar results were reported by Sands and Wright (1980) and by Richardson and Kresch (1983).

DISCUSSION

The present study demonstrated that pigeons can learn to (1) peck a sample key 3 to 15 times until it produces a matching comparison stimulus, (2) continue to peck a sample and frequently avoid responding to presentations of up to four nonmatching comparison stimuli, (3) match eight different

Fig. 8. Cumulative errors (including repeated trials) emitted during trials in which novel stimuli served as samples. Each data point represents a mean taken over two consecutive sessions, except (*), which denotes single sessions. The number above each panel identifies the phase. The lower number in each panel, e.g., 9 T, shows the number of trials per session that the bird had to match the novel sample.

stimuli, seven of which are figures, during each session, and (4) show matching transfer or facilitated acquisition with novel samples.

Zentall and Hogan (1978) trained pigeons with the MTS procedure and provided negative instance trials (trials with two non-matching comparison stimuli) for half their birds. If the bird did not peck either non-matching comparison stimulus for 3 s, the next trial was presented. They reported that the birds trained with negative instance trials produced superior matching transfer to new stimuli; mean group accuracy during the first transfer session was 87.7%. They suggested that negative trials may facilitate transfer and concept learning in nonhumans. Zentall et al. (1980), employing the OFS paradigm, reported similar results.

Fujita (1983) and Urcuioli (1977) also suggested that the establishment of concep-

tual behavior (as evidenced by transfer to novel stimuli) is facilitated when the animals are taught to not respond during certain trials. In a related paper, Urcuioli and Nevin (1975) attempted to facilitate matching transfer by teaching S^A (do not peck non-matching comparison stimuli) as well as S^D relations (peck the matching comparison stimulus). The present study also provided negative stimulus conditions with respect to matching. The bird was frequently in the presence of between one and four nonmatching comparison stimuli. The initial presence of nonmatching stimuli may have facilitated transfer to novel samples.

Several researchers have reported that matching sample forms is more difficult to establish than matching hue stimuli (e.g., Cumming & Berryman, 1965; Farthing & Opuda, 1974). Others (e.g., Delius &

Habers, 1978; Herrnstein, 1979; Herrnstein et al., 1976) have shown that under certain conditions pigeons can discriminate well between complex stimuli. The birds in the present study maintained 60 to 98% matching accuracies with five (of a possible eight) complex comparison stimuli available, showing accuracy levels far above those predicted by chance (20%). This is not surprising; several papers have suggested that transfer can be facilitated by initially training subjects with a large number of stimuli (e.g. Holmes, 1979; Honig, 1965; Levine & Harlow, 1959; Malott & Malott, 1970; Mishkin & Delacour, 1975; Pisacreta & Witt, 1983; Urcuioli & Nevin, 1975), or by increasing the number of incorrect comparison stimuli (e.g., Nissen & McCulloch, 1937; Pastore, 1954; Zentall et al., 1980). For example, Zentall et al. (1980) reported 65 to 80% matching accuracies with three response keys, and 85 to 95% accuracy levels when five keys were employed. Sands and Wright (1980) trained monkeys to push a "T" lever one way if two consecutive stimuli (fruit, flowers, animals, or people) were the same, and to push the lever in the other direction if the stimuli were different. They used 211 stimuli. The monkeys were also able to indicate with 65 to 95% accuracy whether a sample was one of 20 stimuli they had previously seen. Herrnstein et al. (1979) used over 1600 stimuli in their study.

Blough (1979) pointed out that accuracy of responding in search situations may be a reasonable indicator of recognition and attention mechanisms in nonhumans. With the present procedure the birds pecked the sample, scanned the sequential comparison stimuli, and frequently shifted their response to the comparison stimulus that matched the sample as soon as it was presented. Because figure stimuli were used, matching was probably based on stimulus properties more difficult for us to assess than those of simple hues. The transfer to new samples might be interpreted in terms of stimulus generalization, but such an interpretation usually appeals to some physical dimension such as

wavelength or intensity of light, or frequency or decibel levels of sound. Like Herrnstein et al. (1976), we cannot identify any relevant physical element common to all the stimuli we employed.

The interpretation of matching as an example of three-key discrimination (the configuration model) seems untenable in the present study. The birds would have had to acquire 30 different three-, four-, and five-key discriminations. Premack (1978) claimed there were three limitations to matching transfer in pigeons. The birds cannot (1) extrapolate to new stimuli, (2) transfer to orthogonal stimulus dimensions, and (3) make true same-different judgments. Premack's criteria for concept learning require the animal to "show savings in learning the new problem" or "perform as accurately on the new problems as on the training ones" (p. 428). Premack pointed out that pigeons respond more to absolute values of stimuli than to relational factors, a factor that severely limits transfer ability. The birds in the present study had to overcome each of Premack's limitations in order to do as well as they did. They also showed "savings in learning." Figure 8 shows that the birds matched novel samples errorlessly within 9 to 20 trials. These results were produced although the procedure may have been biased against transfer. Zentall and Hogan (1978), among others, have suggested that transfer tests that present novel samples with familiar stimuli as incorrect comparison stimuli may disrupt transfer. The birds tend to choose familiar (incorrect) comparison stimuli with which they have a reinforcement history, instead of choosing novel matching-comparison stimuli. The results of this study suggest that sequential rather than simultaneous comparison stimulus presentation reduces this tendency.

The "multiple rule" two-component chain model can probably be used to explain any transfer data that are less than errorless. Nevertheless, presenting several matching problems consisting of complex stimuli, on multiple response keys, with initial negative matching conditions seems a viable approach

to producing conceptual-type behavior in pigeons. The speed of acquisition on novel matching problems, including additional keys and stimuli, suggests that the birds did learn, to some degree, the concept of figure matching.

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