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TRANSFER OF HUE MATCHING IN PIGEONS[1]

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Pigeons were trained on a modified three-key matching-to-sample procedure, in which only one comparison key (rather than two) was lighted after an observing response to the center-key standard. Pecks on keys of matching comparison hues were reinforced. When nonmatching hues appeared as the initially lighted comparisons, the nonmatching hue terminated and the matching hue appeared on the other side key only if the pigeon did not peck the nonmatching comparison for 4.8 sec. Pecks to the nonmatching hue reset the 4.8-sec delay interval. Three hues were used during acquisition. During transfer tests, two novel hues were substituted individually or together for one or two of the training hues. Latencies to the novel side-key hue were shortest when a novel matching hue appeared as the standard on the center key, and were essentially identical to baseline matching latencies. In contrast, when a novel hue appeared as either a standard or comparison in a nonmatching combination, latencies increased with increasing separation between the novel hue and the nonmatching hue. These transfer data demonstrate the concept of hue matching.

Key words: matching-to-sample, transfer, concept of matching, hue dimension, key peck, pigeons

Cumming and Berryman (1961) reported that pigeons trained to high levels of accuracy on a three-key simultaneous matching-to-sample task did not exhibit transfer to a novel hue. Farthing and Opuda (1974) showed that pigeons do not exhibit transfer even if they have a history of reinforcement for pecking the novel hue outside the matching context. These data, together with related findings (Cumming, Berryman, and Cohen, 1965), suggest that pigeons in a matching-to-sample experiment learn only a set of specific "S^D rules" (for example, "if red on center, peck red on side", "if green on center, peck green on side", "if blue on center, peck blue on side"). When novel stimuli are presented during transfer tests, the matching performance does not generalize. This implies that the S^D rules learned during matching training are specific to the set of training stimuli. Stated otherwise, the pigeon has not learned the general concept of matching. Conceptual behavior may be defined as generalization within a class of stimuli, and discrimination between classes (Keller and Schoenfeld, 1950). The relevant class for reinforcement in this instance is defined by the identity of the center- and side-key hues, while the relevant class for nonreinforcement is defined by hue difference. Control by these stimulus classes would be demonstrated by transfer of performance from the particular hues used in training to novel hues where the identity and difference relations are maintained.

The failure to transfer matching performance to novel hues is surprising, because pigeons give clear evidence of transfer in closely related situations. For example, Honig (1965) demonstrated the transfer of a sameness-difference discrimination in a procedure that reinforced responses to one of two keys if both were lighted alike, and to the other if the keys were different. Malott and Malott (1970) observed transfer in a single-key situation, where their pigeons were required to refrain from pecking for 30 sec when the halves of the key were different, after which the two halves were lighted the same and pecking was reinforced. The procedures used by Honig and the Malotts are similar in that two different contingencies (peck one or the other of two keys, or peck *versus* refrain from pecking) were arranged successively in the presence of matching and nonmatching stimuli. By contrast, the standard

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three-key procedure arranges reinforcement for pecking the matching key and extinction for pecking the nonmatching key concurrently within each trial. As a consequence, a pigeon trained on the standard three-key procedure can achieve high levels of accuracy by learning only to peck the matching key (*i.e.,* learning only a set of S^D rules), without learning explicitly to refrain from pecking the nonmatching key.

Matching performance in the three-key procedure may fail to transfer because the pigeon does not learn to refrain from pecking the nonmatching key. Thus, pigeons given explicit training not to peck nonmatching hues may transfer matching to novel hues. The following experiment used a three-key matching procedure similar to that of Cumming and his associates, except that only one of the side keys was lighted at a time after the pigeon made an observing response to the center-key standard. If the side-key hue was the same as the center-key hue, a peck produced food. If its hue was different, the pigeon had to refrain from pecking for a brief period, after which the other side key was lighted with the matching hue and food was available for pecking it. After training to asymptote with three hues, transfer was assessed with two novel hues.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons were reduced to 80% ± 15 g of their free-feeding body weights and were not studied on days that their weights exceeded or fell below the 15-g limits.

Apparatus

The translucent keys in a standard three-key Lehigh Valley pigeon chamber could be lighted red, yellow, green, blue, or violet by pilot lamps (Sylvania type 24 ESB) covered with colored filter caps (types 38001, 38002, 38004, and 38005). For violet light, the 38005 cap was covered with purple cellophane. Because calibrating equipment was unavailable, the resultant hues can be specified only nominally. It is reasonable to assume, though, that hues for the pigeons were at least ordinally related to the experimenters' hue names (Schneider, 1972). The chamber was illuminated throughout each session by a houselight above the center key. Mixed grain could be presented in a lighted magazine below the center key. The chamber blower provided some masking noise throughout each session. Conventional electromechanical scheduling and recording equipment was in an adjacent room.

Procedure

Preliminary training. Birds were given an initial session of magazine training. During a subsequent session, the center key was lighted with either a red (R), a green (G), or a yellow (Y) light, in random order. A single peck on the lighted key was reinforced with 3-sec access to grain. After 45 reinforcements, the left- and right-side keys were lighted in random fashion with either an R, G, or Y light. Pecks on the lighted side key were reinforced independent of location and hue. Side-key training continued for 60 trials. During the final phase of preliminary training, all keys were lighted singly and in random order with the colored lights. Only a single peck on the lighted key was reinforced; pecks on a dark key were not reinforced. An intertrial interval (ITI) of 5 sec intervened between successive key illuminations. The houselight remained on during each trial and was off during presentation of food and during the ITI. After 45 trials with this contingency, the experimental procedure began.

Matching procedure. Figure 1 schematically represents the matching procedure. Each session began with a 20-sec ITI. At the end of the ITI, the center key was lighted. A single peck on the center key lighted either the left- or the right-side key but not both. If the side-key hue matched that on the center key (a matching trial), a peck on the lighted side key was reinforced with 3-sec access to grain. A new ITI then followed. If the side-key hue did not match the center-key hue (a nonmatching trial), the nonmatching side-key hue terminated and the matching hue on the other side key appeared when the bird refrained from pecking the side key for 4.8 sec. A peck to the matching hue was then reinforced and a new 20-sec ITI followed. Each time a peck was made on the nonmatching side-key hue, however, the 4.8-sec delay interval was reset.

The center-key hue remained on during side-key illumination. Additional pecks on the center key during side-key illuminations had no scheduled consequences, nor did pecks on the

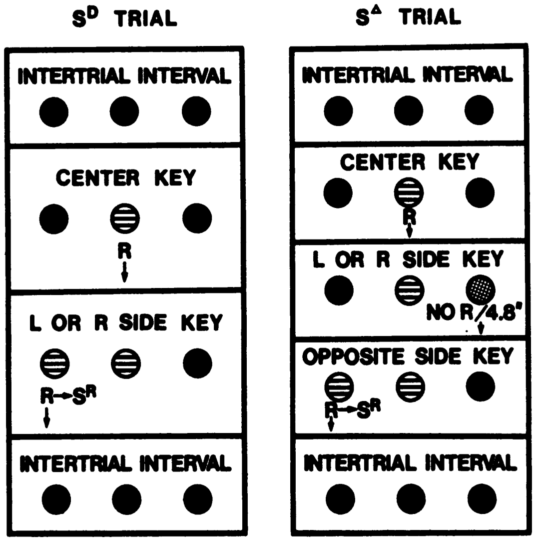

Fig. 1. Schematic representation of procedure. See text for details.

dark side keys. The bird could thus peck the center key or dark side keys while a nonmatching side-key hue appeared without resetting the 4.8-sec delay interval.

Each trial ended with reinforcement, followed by a 20-sec ITI. Keylights went off with food presentation and remained off during the ITI. The houselight remained on during each trial and ended with food presentation, remaining off during the subsequent ITI.

The center-key hue was either R, G, or Y, determined in a quasirandom order such that each hue appeared equally often during each session. Which side key was lighted following a center-key peck was determined by a probability generator. In addition, a probability generator set at 0.50 determined whether the initial side key was lighted with the matching hue (a matching trial) or a nonmatching hue (a nonmatching trial).

Daily sessions of 75 trials were conducted six days per week. During 36 days of acquisition, data were recorded for each trial. During the subsequent 14 days of baseline, data from the first 12 and the last 13 trials were discarded. Following baseline, the birds were tested for transfer of the matching performance to novel stimulus hues.

Testing. During each of four transfer tests a novel hue was substituted for one of the original training hues. Each transfer test consisted of four sessions. Eight days of baseline training intervened between tests. The reinforcement contingencies of acquisition and baseline remained in effect during testing. Table 1 lists the nonmatching hue combinations during acquisition and baseline, and during each transfer test. The matching hue combinations are not listed but correspond to those pairs formed by each of the three hues during each test. For example, R-R, G-G, and Y-Y are the matching hue pairs during acquisition and baseline, while R-R, B-B, and Y-Y are the matching pairs during Test I.

A novel blue (B) hue was substituted for the original green (G) training hue during Test I. The stimulus pairs of interest were those nonmatching hue combinations formed with the novel B hue (*i.e.*, B-R, B-Y, R-B, and Y-B) and the matching B combination (B-B). During Test II, a novel violet (V) hue replaced the original green (G) training hue. As in Test I, the stimulus pairs of interest were the nonmatching combinations formed with violet (V), and the matching V-V combination. The final two transfer tests exhausted all possible nonmatching hue combinations formed with the three training hues and the two test hues: R, G, Y, B, and V. In Test III, B and V replaced R and G, yielding the novel nonmatching combinations B-V and V-B. In Test IV, B and V replaced R and Y, yielding the novel nonmatching combinations B-G, G-B, V-G, and G-V.

RESULTS

Matching latency was the latency of the first peck to an initially lighted matching side key (a matching trial). Matching latencies were re-

Table 1

Nonmatching stimulus combinations during each phase of the experiment. Matching stimulus combinations were the matching pairs of hues. Matching and nonmatching hues appeared randomly on the left- or right-side key.

Acquisition and Baseline	*Test I*	*Test II*	*Test III*	Test IV
R – G	R – B	R – V	B – V	B – G
R – Y	R – Y	R – Y	B – Y	B – V
G – R	B – R	V – R	V – B	G – B
G – Y	B – Y	V – Y	V – Y	G – V
Y – R	Y – R	Y – R	Y – B	V – B
Y – G	Y – B	Y – V	Y – V	V – G

corded on matching trials only, and not on those trials in which a nonmatching comparison appeared on the initially lighted side key. Matching latencies were recorded for each matching hue pair. Mean S^D latency refers to the average of the mean latencies for each matching hue pair.

Nonmatching latency was the latency of the first peck to the initially lighted nonmatching side key (a nonmatching trial). If no peck occurred to the nonmatching comparison for 4.8 sec, the nonmatching hue ended and the matching hue appeared immediately on the other side key. Hence, the absence of a peck on any given nonmatching trial was recorded as a 4.8-sec latency. Nonmatching latencies were recorded for each of the six possible nonmatching hue combinations. Mean S^Δ latency refers to the average of the mean latencies for each nonmatching hue pair.

Figure 2 shows the mean S^D and mean S^Δ latencies for each bird during the 36 sessions of acquisition. Mean S^D latencies were longer than mean S^Δ latencies for at least the first 10 sessions of acquisition for each bird. This effect was partly artifactual: nonmatching latencies could not exceed 4.8 sec, and matching latencies had no upper limit. Performance on nonmatching trials was characterized by consistently short latencies and repetitive responding to the nonmatching hues, generally independent of the specific nonmatching hue pair. By Session 15, the mean S^Δ latency exceeded the mean S^D latency, primarily because matching latencies decreased. Smaller increases in nonmatching latencies accompanied the decreases in matching latencies. The first consistent 4.8-sec nonmatching latencies occurred around Session 20 for Bird 91 and Session 25 for Bird 93. Bird 92 began to show consistent 4.8-sec latencies around Session 12. For Birds 91 and 92, asymptotic mean S^D latencies, computed over the last four sessions of acquisition, were 1.0 sec. The asymptotic mean S^Δ latencies for these two birds were 4.2 and 4.3 sec, respectively. Bird 93 acquired the matching task more slowly and was more variable in day-to-day performance than were the other two. Nonetheless, there was a clear separation between Bird 93's asymptotic mean S^D and S^Δ latencies: 1.4 and 3.5 sec, respectively.

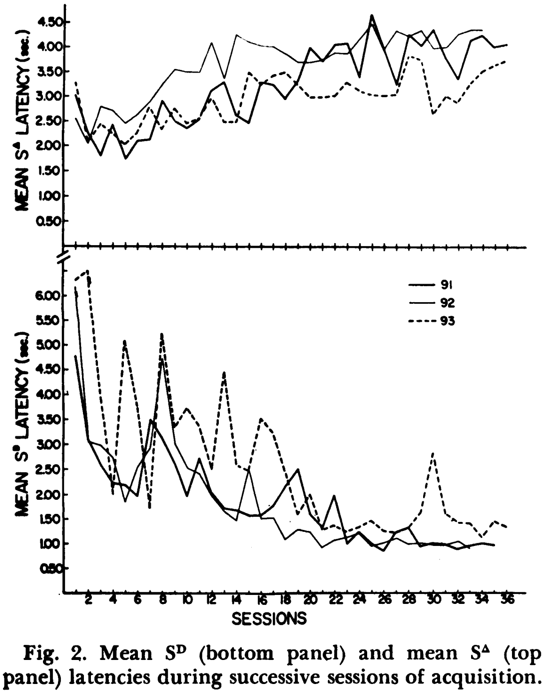

Fig. 2. Mean S^D (bottom panel) and mean S^Δ (top panel) latencies during successive sessions of acquisition.

During baseline sessions, the first 12 and the last 13 trials of each day's data were discarded to reduce the day-to-day variability in the latencies, especially the nonmatching latencies. Because most of the responding to the nonmatching stimuli typically occurred during either the initial or the terminal nonmatching trials within each session (reflecting warm-up and satiation effects, respectively), eliminating these trials from the data increased the mean S^Δ latencies. There was no corresponding decrease in the mean S^D latencies. During the baseline phases between transfer tests, the matching performance was comparable to pretest levels of performance.

The progress of acquisition for Bird 91 was representative of all birds. Sample latencies during three sessions of acquisition and during the last day of the initial baseline phase for Bird 91 are shown in Table 2, in which mean S^D and S^Δ latencies have been broken down by hue pair.

Matching latencies were generally longer than nonmatching latencies during the first acquisition session. By Session 11, all matching latencies had decreased considerably from their initial levels, although nonmatching latencies did not consistently increase. Data from Session 31 show asymptotic performance for Bird 91. Matching latencies were approximately 1.0 sec, while nonmatching latencies were greater than 4.0 sec, except hue-pairs R-Y and Y-R.

Table 2

Mean S^D and mean S^Δ latencies (in seconds) by hue pairs for Bird 91 during three sessions of acquisition and the last session of initial baseline.

	Sessions			
Hue Pairs	*1*	*11*	*31*	*Base 14*
R - R	4.5	2.2	0.8	0.9
G - G	3.8	2.0	1.0	1.0
Y - Y	6.1	1.7	1.0	0.8
R - G	3.6	2.4	4.8	4.8
R - Y	2.8	2.9	3.9	3.6
G - R	2.0	3.0	4.3	4.8
G - Y	4.2	3.0	4.2	4.8
Y - R	3.9	1.8	3.9	4.8
Y - G	1.8	2.2	4.8	4.8

Matching latencies during the last session of baseline were less than 1.0 sec, and all but one nonmatching latency were the maximum 4.8 sec.

Table 3

Mean latency of response to the initially lighted side key during the first session of each test for transfer of matching performance. The center-key hue is given first and the side-key hue second. Data are presented only for the first test in which each novel hue pair appeared. Matching hue pairs are underlined. Mean S^D and S^Δ latencies are given at the top of each column for comparison.

Baseline	*#91*	*#92*	*#93*
S^D	*1.0*	*1.0*	*1.4*
S^Δ	*4.4*	*4.5*	*3.6*
Novel Hue pairs			
B - B	0.8	1.0	0.9
V - V	1.1	1.4	1.9
B - V	2.4	3.4	1.0
V - B	2.4	2.4	1.7
B - R	4.8	4.8	1.4
R - B	4.3	3.5	1.8
B - Y	4.0	4.8	2.5
Y - B	4.4	4.1	0.9
V - R	1.6	2.4	1.2
R - V	1.8	3.4	1.2
V - Y	3.5	2.7	4.4
Y - V	3.9	4.8	1.2
B - G	2.4	1.4	0.8
G - B	0.7	2.4	1.4
V - G	2.6	3.9	4.2
G - V	4.8	4.4	4.2

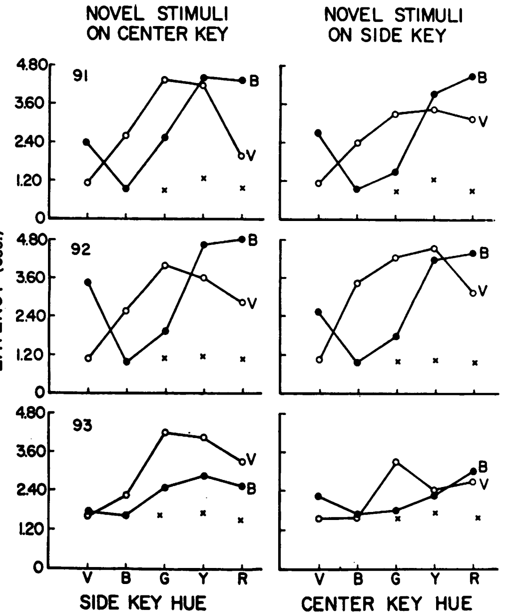

Fig. 3. Pooled transfer data. Left column: latency to the side-key hue when a novel hue appeared on the center key. Right column: latency to a novel side-key hue as a function of the center-key hue. Functions described by filled circles are for the novel blue stimulus; open circles are for the novel violet stimulus. Crosses indicate baseline S^D latencies.

After the initial baseline phase, four tests examined transfer of matching. During each transfer test, a novel hue was substituted for one of the original training hues. Table 3 presents the mean side-key latencies for all novel hue combinations during the first day of testing with each combination. For Birds 91 and 92, latencies to novel matching side-key hues (B-B and V-V) are essentially the same as baseline matching latencies. Latencies to nonmatching side-key hues (B-V, V-B, *etc.*) are almost without exception longer than to matching hues. Some latencies to novel nonmatching hue combinations are as long as baseline nonmatching latencies (*e.g.*, B-R, R-B, Y-B, B-Y). Thus, two birds clearly show evidence of transfer during initial exposure to novel hue combinations. Bird 93 failed to exhibit transfer during these initial test sessions.

Data pooled for all four transfer sessions with each hue combination are presented in Figure 3. The left column presents the side-key latencies as a function of novel center-key hue. The function described by the filled circles is for the novel blue stimulus and the open circles describe the function for the novel violet stimulus. Latency to the side key was shortest when the side-key hue matched the novel center-key hue (a matching trial). When the novel stimulus on the center key was blue, latencies to the side key were longer the greater the separation between the side-key hue and the novel blue stimulus on the ordinal hue continuum. A similar function was obtained when the center key was violet. In addition, transfer latencies when the side-key hue matched the center-key hue were essentially identical to baseline matching latencies, as shown by the baseline matching latencies for the original training hues (crosses).

The right column of Figure 3 presents latencies to the novel side-key hues (B or V) as a function of center-key hue. Again, latencies were shortest when the center key matched the novel side-key hue (a matching trial) and latencies increased with increasing separation between the center-key hue and the novel side-key hue on the ordinal hue continuum. The forms of the functions are the same for Birds 91 and 92. The apparent transfer of Bird 93 is an artifact of the pooled data, which include acquisition over sets of test sessions. If the data of Table 3 were plotted in the same format as Figure 3, the function forms would be similar. Thus, except for Bird 93, the similarity of these functions suggests that the pooled transfer data should not be ascribed to acquisition across test sessions.

To summarize the transfer data: response latencies were shortest on matching trials with novel stimuli and were just as short as the matching latencies with the original training hues. Latencies for nonmatching trials with novel hue pairs were longer than for matching trials and increased as a function of the separation between the nonmatching hues along the ordinal hue continuum.

DISCUSSION

In the usual three-key simultaneous matching procedure, an observing response to the center key illuminates both side keys simultaneously. Pecks on the matching side key are reinforced, while pecks on the nonmatching side key are followed by timeout. Because these contingencies are scheduled concurrently, high levels of performance can be achieved if the pigeons learn only a set of S^D rules (Berryman, Cumming, Cohen, and Johnson, 1965). In other words, the pigeons may learn only which comparison hues are correct (*i.e.*, matching), without learning which are incorrect (*i.e.*, nonmatching). The S^D rules appear to be specific to the stimuli used during matching training, in that the pigeons do not exhibit transfer of the matching performance to novel hues during testing.

The failure to transfer matching to novel stimuli, then, reflects the failure of the pigeons to learn which comparison hues are incorrect or nonmatching. We have shown that if pigeons are explicitly trained not to peck nonmatching hues, they will transfer matching performance. By successively, rather than concurrently, arranging two different contingencies in the presence of matching and nonmatching stimuli, the present procedure ensured that the pigeons discriminated nonmatching hue combinations as well as matching combinations. The pigeons may have learned nine specific performance rules with our matching contingencies (*e.g.*, "if red on center and yellow on side, do not peck yellow on side", "if red on center and green on side, do not peck green on side", and "if red on center and red on side, peck red on side", *etc.*) The transfer data, however, suggest that the pigeons learned two general rules instead: "if side-key hue same as center-key hue, peck side key", and "if side-key hue different than center-key hue, do not peck side key". The first of these general rules appears to have generalized completely to novel hues, in that S^D latencies to novel hues during transfer testing did not differ from S^D latencies during baseline (Figure 3 and Table 3). The second of these rules did not, however, generalize completely: S^Δ latencies depended on the separation between the standard and comparison hues on the ordinal hue continuum. For example, when blue was the novel standard hue, the shortest side-key latencies occurred when blue also appeared on the initially lighted side key. When blue was the novel standard hue and green appeared as the comparison hue, side-key latencies were longer than the corresponding S^D latencies but shorter than those latencies when yellow appeared as the comparison. Latencies were ordered from fairly short to quite long as the side-key hues were increasingly different from the center-key hue.

Schneider (1972) found that color space is circular for pigeons, as it is for humans. The assumption that the experimenters' hue names in our study corresponded at least ordinally to the hues of the spectral stimuli in Schneider's study is corroborated by the latency data. Given this assumption, side-key latencies should be shorter to red than to yellow or green when violet appears on the center key, because red is closer to violet on the color circle. The data verify this prediction, thus providing further support for the circular nature of color space for the pigeon.

Finally, it is important to distinguish between the demonstration of a concept such as matching, which requires successful transfer to novel stimuli, and transfer based on a coding response (*cf.* Cumming *et al.,* 1965). Cumming and his associates argue that subjects code or name the center-key hue in a matching-to-sample experiment (*e.g.,* Wright and Cumming, 1971) and then respond to the side-key hue on the basis of that coding response. For example, a novel yellow hue may be coded as red, with the result that the subject responds to red (as a comparison on a side key) when yellow is presented as a standard (on the center), exactly as if red had been presented on the center. Coding of this sort could serve as a basis for transfer. For example, if pigeons were initially trained on a matching-to-sample task with red, green, and blue, and then tested for transfer with yellow substituted for red, transfer could be perfect if yellow were coded as red. Although we do not question the operation of a coding mechanism of this sort in many experiments, it cannot account for our data. Consider the transfer tests in which red or yellow was replaced by blue. If blue were coded as green, for example, latency to green on a side key should be at least as short as the latency to the novel blue hue on a side key. But this was not the case: latency to green was longer than to blue. Other plausible coding examples encounter the same difficulty. We suggest, therefore, that transfer to novel hues was not based on mediation by codes for the center-key hues employed in training, but demonstrates the general concept of matching.

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