

ACQUISITION OF DELAYED MATCHING IN THE PIGEON¹

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Pigeons were exposed to three successive matching-to-sample procedures. On a given trial, the sample (red, green or blue light) appeared on a center key; observing responses to this key produced the comparison stimuli on two side keys. Seven different experimental conditions could govern the temporal relations between the sample and comparison stimuli. In the "simultaneous" condition, the center key response was followed immediately by illumination of the side key comparison stimuli, with the center key remaining on. In "zero delay" the center key response simultaneously turned the side keys on and the center key off, while in the "variable delay" conditions, intervals of 1, 2, 4, 10, and 24 sec were interposed between the offset of the sample and the appearance of the comparison stimuli on the side keys. In all conditions, a response to the side key of matching hue produced reinforcement, while a response to the non-matching side key was followed by a blackout. In procedure I all seven experimental conditions were presented in randomly permuted order. After nine sessions of exposure (at 191 trials per session, for a total of 1719 trials) the birds gave no evidence of acquisition in any of the conditions. They were therefore transferred to Procedure II, which required them to match only in the "simultaneous" condition, with both the sample and comparison stimuli present at the same time. With the exception of one bird, all subjects acquired this performance to near 100% levels. Next, in Procedure III, they were once more exposed to presentation of all seven experimental conditions in random order. In contrast to Procedure I, they now acquired the delay performance, and were able to match effectively at delays of about 4 sec.

In the matching-to-sample task, the subject's choice-response must be based on some common property of the sample and comparison stimuli. Since correct performance is based on two stimuli, rather than one, the discrimination is said to be "conditional" (Lashley, 1938). It is therefore considered to represent a "higher mental process" involving not a single, specific response, but rather a larger and more complex segment of behavior. For this reason, following its introduction by Kohts (1928), the matching procedure has been used extensively in the study of discriminative processes.

If a temporal interval is interposed between the presentation of the sample and the appearance of the comparison stimuli, the matching procedure makes contact with the problem of delayed responding (Hunter, 1913). In fact, it offers obvious advantages for studies in this area, since correct performance cannot be achieved by spatial orientation alone.

Most, if not all, studies of delayed responding have involved progressive lengthening of the delay interval. The amount of training for different delay intervals is therefore left uncontrolled, and no clear comparison of the acquisition functions for the different delays is possible. This difficulty is avoided by using a procedure which equates amount of training on a number of different delay intervals.

METHOD

Subjects

Seven white Carneaux pigeons were maintained throughout the experiment at 80% of their free-feeding weights.

Apparatus

The same as that used in an earlier study (Cumming and Berryman, 1961), it consisted of a triangular aluminum cage with three keys and a grain magazine on one wall. For this experiment, the cage was given some measure of sound insulation by enclosing it within a box with 2-in. fiberglas walls. An air blower provided ventilation and some

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masking noise. A small, half-silvered glass window made it possible to observe the animals as they worked.

In preliminary training, the subjects were reinforced for pecking the keys when they were transilluminated with red, green or blue light. Approximately equal numbers of reinforcements were provided on the left, center and right keys, and in the presence of each of the three hues.

Procedure I

All birds were then immediately placed on Procedure I, which exposed them to "simultaneous," "zero delay," and "variable delay" conditions. Under all conditions, a trial was initiated by illuminating the center key with red, green or blue light. In the "simultaneous" condition, a response to this key resulted in the illumination of both side keys, one of which matched the center key hue, while the other was one of the two remaining non-matching hues. A response to the side key of matching hue resulted in a 3-sec presentation of the grain magazine; following a response to the key of non-matching hue, all illumination in the cage was turned off for 3 sec. In either case, all keys were darkened. A 25 sec intertrial interval (during which all keys were dark and all responses ineffective) followed either reinforcement or blackout, and ended with the presentation of the next trial.

The "zero delay" trials differed in that the center key response simultaneously turned off the sample hue on this key, and turned on the side key comparison stimuli. "Variable delay" trials consisted of the insertion of a temporal delay between the offset of the center key light and the onset of the side key lights. During the delay interval, responses to any of the keys (all of which were then dark) had no effect.

Five different delays were used: 1, 2, 4, 10, and 24 sec. Thus there were seven different experimental conditions. The requirements that each hue appear equally often on the left and right side keys, and in combination with each of the alternative hues, establish 12 different stimulus conditions. Since each stimulus condition was used with each delay condition, a total of 84 combinations is defined.

Each day's session consisted of 23 practice or "warm-up" trials, followed by 168 experi-

mental trials in which each stimulus-delay combination appeared twice in randomly permuted order. Birds were run every third day, if their weights were within ± 15 gm of the 80% value. Each bird was given a total of nine experimental sessions.

Procedure II

Each of the seven birds was next exposed to the "simultaneous" condition only. The situation was identical with that investigated by Cumming and Berryman (1961), and with the "simultaneous" trials of Procedure I, with the exception that a fixed ratio of five responses on the center key was required for presentation of the side key stimuli. This procedural modification was introduced to provide greater exposure to the sample stimulus. In each experimental session, following 11 practice trials, 84 experimental trials were presented (*i.e.*, each of the 12 stimulus conditions appeared seven times). The order of presentation of the 12 stimulus conditions was taken from a set of random permutations, and was changed several times during the experiment. (Following these changes, no decrements in accuracy were detectable, indicating that the birds were not basing their performance upon stimulus sequence.) Weight permitting, birds were run five days each week for a total of 20 sessions, with the exception that Bird 181 was dropped from the experiment after 16 sessions.

Procedure III

Three of the birds, numbers 170, 171, and 172, were next returned to the conditions of Procedure I, with the exception that the fixed ratio of five on the center key (introduced during Procedure II) was retained, and the session length reduced to 84 trials following 11 practice trials. As before, the sequence of presentation of the stimulus and delay conditions was changed about every two weeks.

RESULTS AND DISCUSSION

Procedure I

None of the seven birds showed any tendency to acquire the matching performance with the randomized presentation of all seven experimental conditions. In fact, the subjects performed at below chance levels on two-

thirds of the experimental sessions.² In addition, the subjects did not exhibit systematic position preferences of the type observed in a previous experiment on the acquisition of simultaneous matching (Cumming and Berryman, 1961). In the earlier data, all three subjects very quickly adopted a position habit which began to break up as the correct matching performance developed. In the present experiment, however, only one of the birds exhibited a comparable position preference—Bird 181 began with, and maintained throughout, an almost total left-key preference. It responded to the right key only 18 times out of

a total of 1612 opportunities. None of these right key responses occurred on the last three days of this procedure. The other six birds showed an entirely different pattern of position preferences. Figure 1 shows the per cent right-key responses for each experimental session, and for each of the seven birds. After some initial fluctuations, right key responding began to cluster around either the 25% or the 75% point, indicating that the birds were making about 75% of their responses to one side key or the other. The reasons for this are not clear and cannot be derived from probability matching formulations (Estes, 1959; Woodworth, 1958).

²A table showing per cent correct matching for each bird for each of the nine experimental sessions of Procedure I has been deposited with the American Documentation Institute. Order Document No. 7151, remitting \$1.25 for 35-min microfilm, or 6-by-8 in. photocopies.

Procedure II

Acquisition of the simultaneous matching performance is given in Fig. 2. The acquisition functions are comparable to those re-

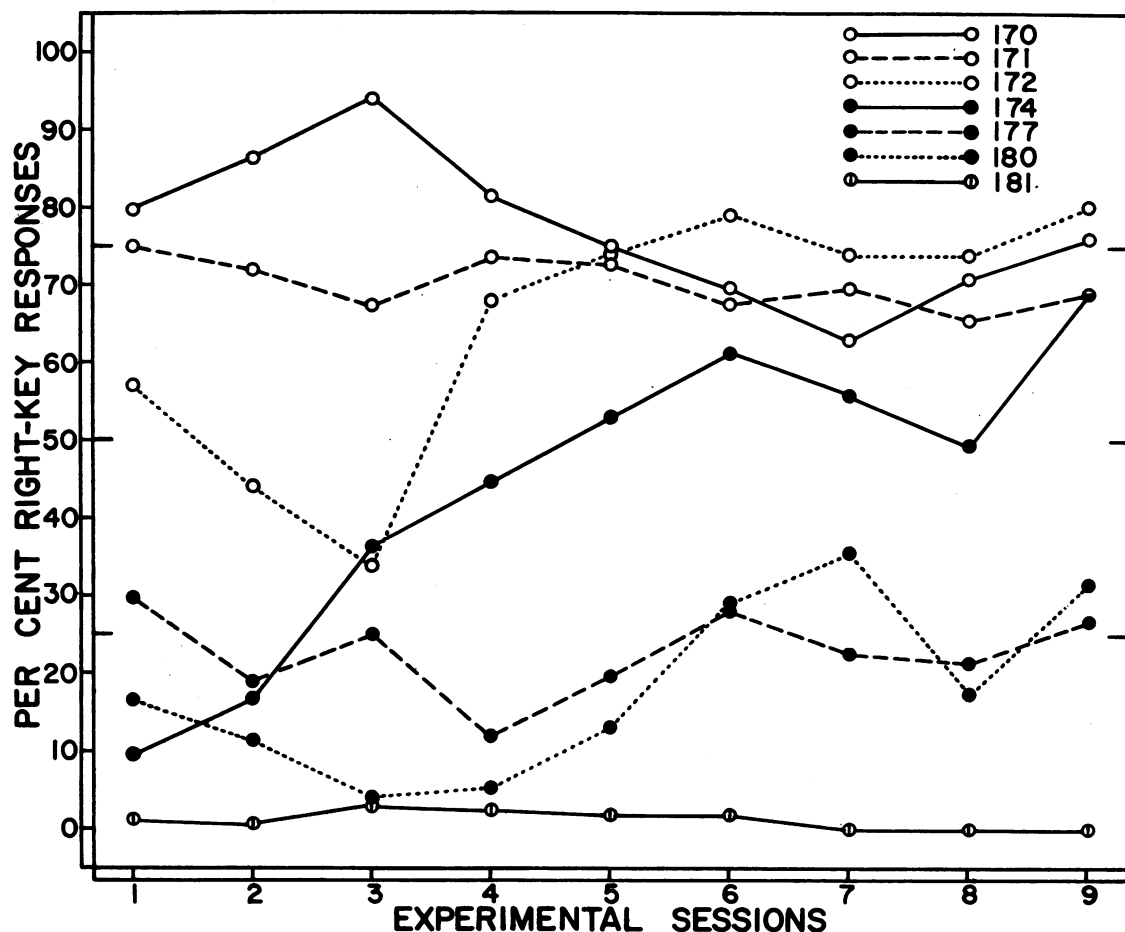


Fig. 1. Per cent right-key responses during the nine days of exposure to Procedure I. The 50% level represents equal responding to the left and right keys.

ported by Cumming and Berryman (1961). The three subjects of that study required between 560 and 840 trials (including practice trials) to reach a 75% performance level, with a group mean of 700. In the present study, the seven subjects reached the same level of performance in from 475 to 855 trials, with a group mean of 705.

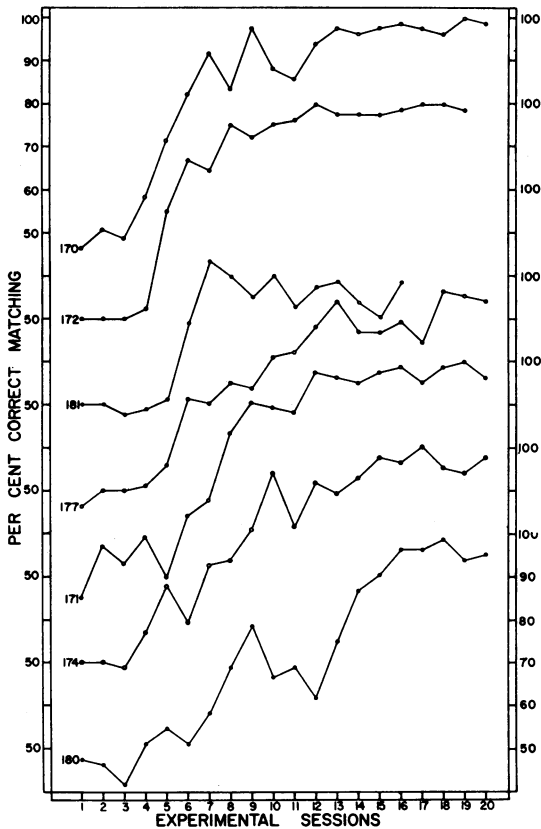


Fig. 2. Acquisition of matching in the simultaneous condition used in Procedure II. The curves for individual subjects are nested in an arbitrary order; each curve has been displaced upward 20% from the one immediately below it.

Accordingly, acquisition appears to have taken much the same course in both studies, even though the subjects of the present experiment had a prior history of about 234 trials on the simultaneous condition, which were, of course, embedded in the 1485 delay trials. The nine sessions' exposure to Procedure I had produced neither positive nor negative transfer to acquisition in Procedure II. Moreover, the additional exposure to the sample stimulus provided by the center

key fixed ratio requirement did not appear to facilitate acquisition of simultaneous matching.

After 16 sessions' exposure, Bird 181 was dropped from the experiment, as this animal had displayed a systematic inability to match blue or green when they appeared as comparison stimuli on the left key, although these hues were matched successfully when they appeared on the right key. In all cases, ability to match red (either on the left or on the right) was normal. Otherwise stated, when all three stimuli were either blue or green, the bird responded to the right key. This performance limited Bird 181 to 83 1/3% correct, since its performance was at chance on one-third of the stimulus conditions.

Another significant aspect of the acquisition of simultaneous matching can be seen in the position preferences. During Procedure I, these preferences (shown in Fig. 1), while systematic, did not coalesce at the near 100% levels (reported in Cumming and Berryman, 1961) which appeared immediately on exposure to the simultaneous condition and persisted until the emergence of the matching performance. Fig. 3 shows the position preferences (in terms of per cent right-key responses) for the final session of Procedure I—labeled "F" in the figure—and for the first 10 days of Procedure II. With the exception of Bird 181, whose case has already been discussed, all birds, when exposed to the simultaneous condition alone in Procedure II, immediately took up a strong position preference. Although the "handedness" of their preferences was related to those previously shown in Procedure I, this is not necessarily the case, as Bird 174's record indicates.

With succeeding sessions the strength of the position preference decreased as the matching performance developed—a finding similar to that reported by Cumming and Berryman (1961). By the tenth session performances clustered around the 50% level, with the exception of two birds (180 and 181) which both showed somewhat deviant acquisition.

Procedure III

Delay gradients (lower panel) and acquisition functions for all experimental conditions (upper panel) are shown in Fig. 4. Certain aspects of the performance should be noted. The simultaneous matching performance be-

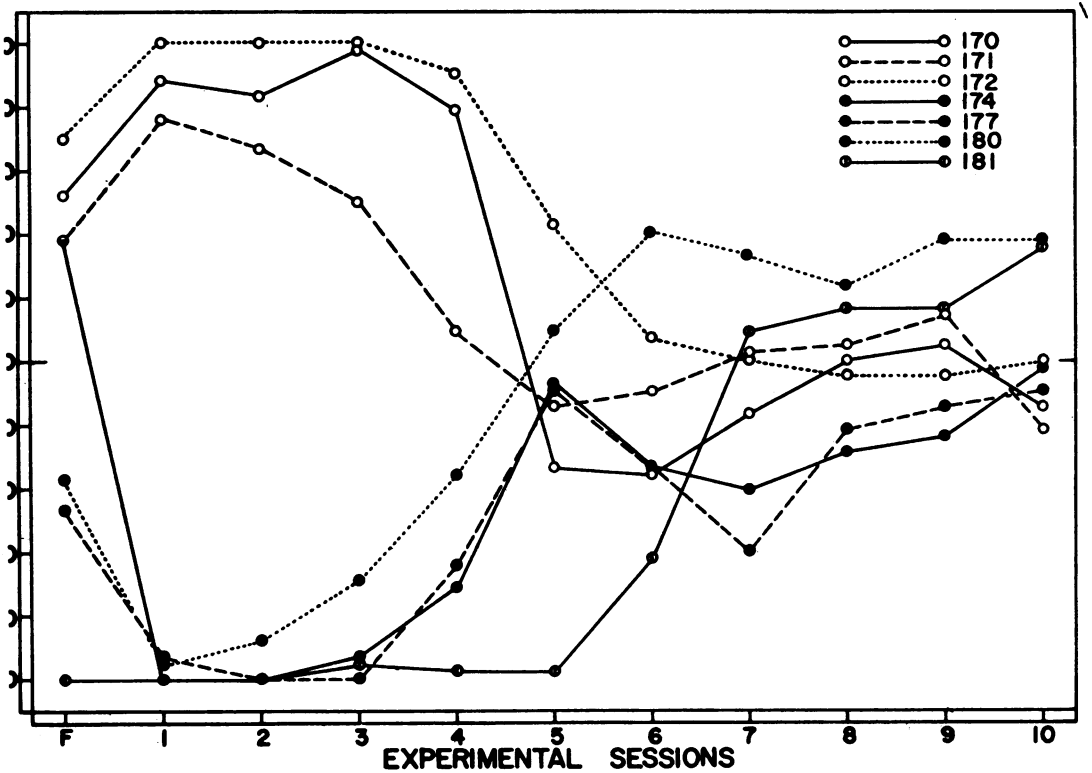


Fig. 3. Per cent right-key responding during the first 10 days of exposure to Procedure II. Data from the final day of exposure to Procedure I are represented as experimental session "F".

gan at a high value that was maintained throughout the entire 60 sessions. Within the first block of 12 sessions, performance was best for the simultaneous condition, zero delay was next, and the 1 and 2 sec delay conditions followed in that order. Chance performance appeared at the 4, 10 and 24 sec delays, with the possible exception of Bird 172, whose accuracy at 4 sec was only slightly worse than at 2 sec. Examination of records for individual sessions shows that all subjects performed above chance on the zero delay condition on the first day of exposure to this procedure. In subsequent sessions, improvement in performance was observed for all conditions up to (and including) the 4 sec delay. By the end of the experiment the order of performance level for all three subjects was simultaneous, zero, 1, 2, 4, 10 and 24 sec.

This order carries with it the suggestion that the observed sequence does in fact represent the order of increasing difficulty of each of the experimental conditions. Since performance levels in the simultaneous condition were

already high at the start of Procedure III, no analysis can be made of the question of whether the experimental conditions represent some continuum of performance or whether they represent qualitatively different kinds of performance. This difficulty arises from the fact that in order to compare the different rates of acquisition, accuracy on initial exposure must be the same in all conditions. This, however, is not the case, inasmuch as there is differential transfer from training in simultaneous matching to the zero delay condition.

The Procedure III data were next analyzed to determine the possible presence of color or position preferences specifically related to experimental conditions. No systematic color preferences were observed. There were, however, some daily variations in color preferences (usually at the intermediate delays) which may represent either chance variation in performance, or fluctuating "stimulus superstitions" such as those described by Morse and Skinner (1957).

While Birds 170 and 171 showed systematic position preferences for some delay conditions early in the experiment, by the end there was no evidence for systematic preferences. Throughout the experiment Bird 172 showed an increasing tendency to right-key responding as delays lengthened. This subject responded to the right key almost 100% of the time at the 24 sec delay.

Blough (1959) observed that pigeons in a matching situation develop repetitive chains of different topography which appear to mediate the delay. Repeated observation failed to disclose any identifiable chains of this type in our subjects. It was, however, ap-

parent that activity during the delay period was quite different in topography from that exhibited during the intertrial interval. The delay interval was usually occupied by "agitated" pacing back and forth in front of the keys, while the intertrial interval was occupied by slower locomotion about the cage.

Since differential chains mediating the delay interval must start during the presentation of the sample stimulus, their presence might be revealed by inspection of quantitative measures of behavior on the center key fixed ratio. Data were therefore taken on the time interval between presentation of the sample stimulus and completion of the ratio. When these data

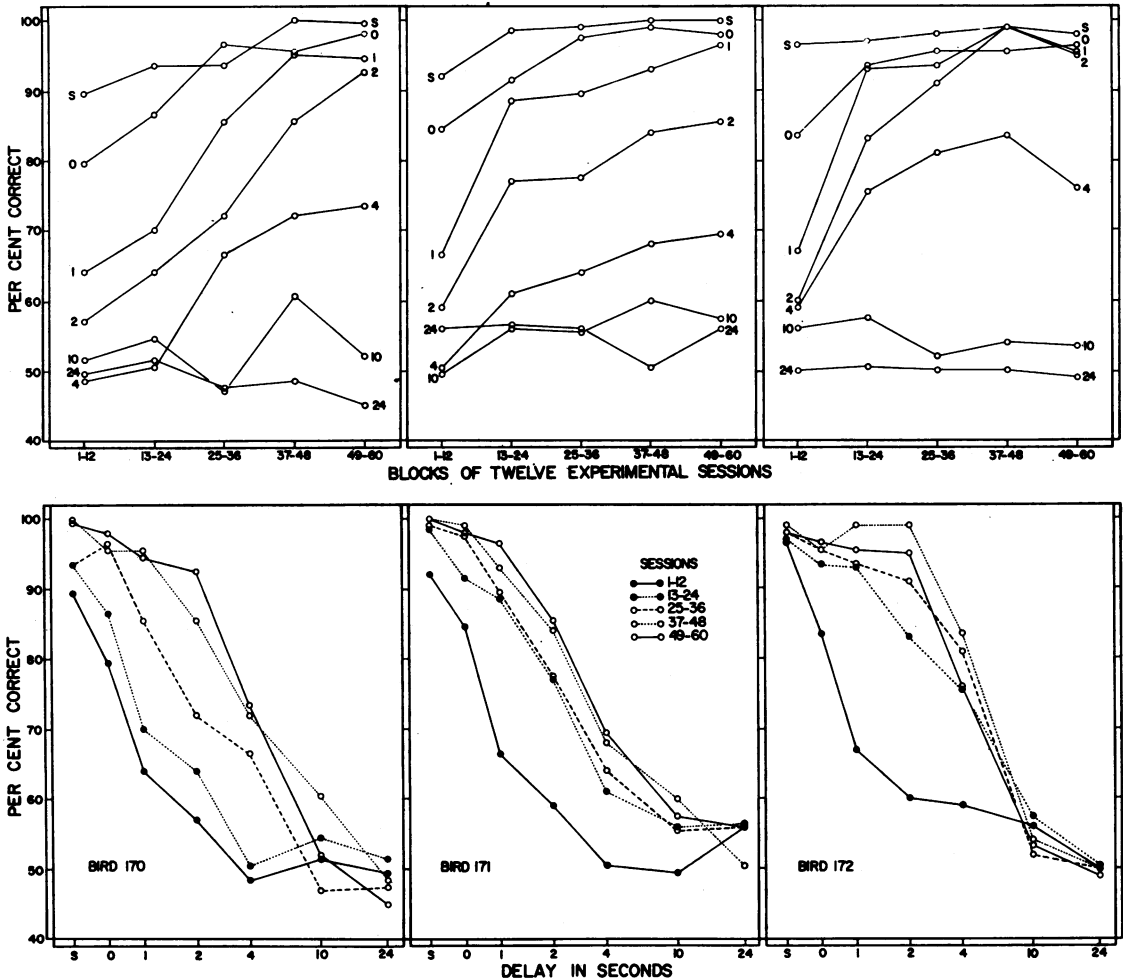


Fig. 4. The lower panel shows the progressive changes in delay gradients for successive 12 session blocks for the three subjects used in Procedure III. The simultaneous and zero delay conditions have both been displaced equal arbitrary intervals to the left of the 1 sec delay. The other delays are plotted on a logarithmic scale. In the upper panel, these same data are displayed as acquisition functions for the simultaneous, and the six delay conditions.

were analyzed by hue, some differences in the latency distributions appeared. Comparisons of these distributions by the Kolmogorov-Smirnov test indicate that Birds 170 and 172 showed consistent differences (in opposite directions) between green and the other two hues, while Bird 171 showed a significant difference between green and blue. This suggests that for at least one of the sample stimuli the rate of execution of the observing response could be considered to be a differential property of the first element of a hue-specific chain. The existence of these individual differences in the size and direction of the latency effects indicates that they are due to individual differences in conditioning history, rather than to some general properties of the stimuli. Latency is, of course, only one of the measures which might have been selected for analysis of the initial member of the hypothetical mediating chain. Under the conditions of our experiment, latency was simply the most accessible metric. Measures of magnitude, topography, *etc.*, might also reveal similar differences.

From the foregoing discussion it is apparent that we cannot assemble unambiguous evidence for the existence of chains during the delay interval. Such chains as our birds may have acquired certainly do not have the distinctive properties reported by Blough (1959). Procedural differences may account for this. In Blough's experiment, conditions for the emergence of different superstitious chains appear to be much more favorable. For one, his birds were first trained on the zero delay condition and then the average length of a set of three delays was progressively increased as the matching performance was acquired. In our case, the full range of experimental conditions was greater than Blough's, as we had not only longer delays but also the simultaneous matching condition. All of these conditions were presented in random order from the outset of the experiment.

Let us suppose that a particular response sequence is reinforced on a given trial. On the next trial with the same sample this sequence may again be emitted. However, a

different experimental condition will now prevail with the consequence that the onset of the comparison stimuli will occur at a different point in the sequence, and perhaps even before it is started if the simultaneous condition happens to be in effect. This situation appears to be highly unfavorable for the formation of chains. In fact, the results of Procedure I and the inferences drawn from Procedure II suggest that even simultaneous matching cannot be acquired with the randomized presentation of experimental conditions.

Furthermore, since Blough did not require an observing response to the sample stimulus, his subjects could engage in a wider range of behavior during its presentation, thus providing a better basis for the emergence of differentiated superstitious chains.

An additional factor is that our experiment, employing three standard stimuli, would require three differentiated chains, while two chains sufficed for Blough's procedure. The specific properties of the stimuli (which also differed) may also have been influential.

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