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DELAYED DISCRIMINATION AND DELAYED MATCHING IN PIGEONS[1]

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Three pigeons were each trained to perform a discrimination problem and a matching problem. Following acquisition, delays of 1 to 7 sec were interposed after stimulus presentation on both problems. Accuracy of responding on these two types of delay procedures was observed to be a function of length of delay interval. Performance was consistently poorer on the delayed matching problem than on the delayed discrimination problem.

In the delayed response experiment the subject emits a response on the basis of a previous discriminative stimulus which is no longer present. Traditional research in this area (Hunter, 1913; Honzik, 1931) has been based on a discrimination paradigm; *i.e.*, the animal is presented with a stimulus signaling where to respond but is not free to select this response until after a delay. More recently, delayed response experiments have been based on a matching-to-sample paradigm (Finch, 1942; Weinstein, 1945); here, in order to select correctly, the subject must remember the stimulus, not merely where to emit a response. The present experiment compared performance on these two types of delayed learning paradigm in the same subject.

METHOD

Subjects

Three White Carneaux pigeons, 2 to 4 yr old, were maintained at approximately 75% of their free-feeding weights during the experimental period.

Apparatus

The test chamber was a Plexiglas box, 40-cm long, 30-cm wide and 30-cm high. A Lehigh Valley translucent pigeon key was located on each of three of the walls, 23 cm from the floor. Visual patterns or an evenly illuminated field could be projected on the keys by a miniature one-plane projector mounted behind each key. An automatic grain dispenser was located on the wall below the center key. The two keys located on opposite walls in the chamber are referred to as the side keys. Figure 1 shows the location of the response keys and the grain dispenser.

A system of relays, timers, and counters automatically controlled and recorded the presentation of stimulus lights, correct and incorrect responses, operation of the grain dispenser, blackouts, delay periods, *etc.*

Procedure

Preliminary training. Pecks on either of the side keys, which were illuminated by white light, were reinforced with 2-to-5-sec access to the grain dispenser. The side keys were darkened and a light went on in the magazine opening while grain was available. Later on, the birds were trained to peck the illuminated center key in order to illuminate the side keys. The center key was darkened while the side keys were illuminated. Subsequently, the visual patterns were introduced and the tabulation of correct and incorrect responses started. In the course of five sessions, the number of pecks on the center key required to darken it and to illuminate the side keys was gradually increased to 20. Each session consisted of 120 trials, and each subject was given one session per day.

In the discrimination problem, the pigeons were required to discriminate a triangle with

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the apex up from a triangle with the apex down. The patterns were projected on the center key in a quasi-random sequence. After pecks on the center key, when the inverted triangle had been presented, a peck on the left side key was reinforced. A peck on the right side key was reinforced after pecks on the center key when the upright triangle had been projected on the center key. After reinforcement for a correct response, a new trial started immediately. Pecks on incorrect side keys were followed by 5 sec of darkness, which was intended to reduce the frequency of incorrect responses. Pecks on the keys during darkness were ineffective. Following an error, a correction procedure was used; the same pattern was projected on the center key, and the whole trial had to be repeated. A new trial was not presented until a correct response was made. Perseverative errors during the correction procedure were not counted.

In the matching-to-sample problem, a vertical or a horizontal bar was projected on the center key. After pecks on the center key, when either of the two bars had been presented, a vertical bar was projected on one of the two side keys and a horizontal bar presented on the other. A peck on the side-key pattern which matched the pattern that had just been projected on the center key was reinforced. A peck on the alternate side key was followed by 5 sec of darkness. Presentation of the bars on the center and side keys was determined by quasi-random sequences. Here, too, a correction procedure was used after errors.

Birds C120 and C134 were first trained on the matching problem. When errors were

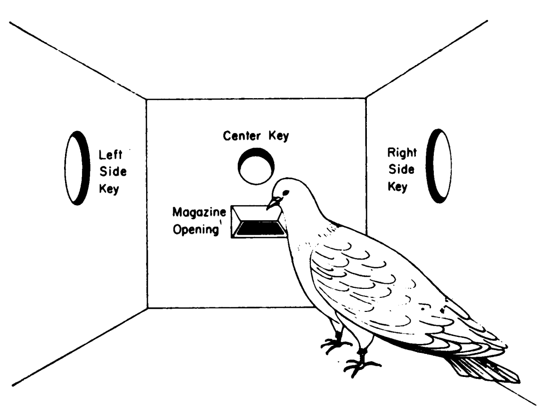

Fig. 1. The experimental chamber, showing location of keys and magazine opening.

10% or less of the total trials on three successive days, the birds were given alternate sessions on the discrimination problem and matching problem. Thus, on days when they were not given the discrimination problem, the birds got additional training on the matching problem. The final criterion of learning was reached when errors were 10% or less of the total trials for six successive sessions; *i.e.*, three successive matching problems and three successive discrimination problems. Bird C121 was trained on the matching problem following acquisition of the discrimination problem; otherwise the training procedure was exactly the same.

Delay Testing. When each subject met the final criterion, delay testing was started. The test phase consisted of a series of training and test sessions on the two problems. On days following training on the matching problem, the subjects were given a delay test based on this problem. The test session consisted of 120 trials, each of which introduced the same delay interval after the stimulus was presented. On the next day, the birds were trained on the discrimination problem. On the subsequent session, they were given a delay test based on the discrimination paradigm, the length of delay being the same as above on each of the 120 trials. During testing, the consequences of correct and incorrect responses were the same as during training. The series of training and test sessions was repeated until the subjects had been tested on delay intervals for the values used in the experiment; thus, 120 test trials were given on each delay interval on both problems. Delay intervals were 1, 2, 3, 4, and 5 sec for all subjects; Bird C134 was also tested on a 7-sec delay interval. For Birds C121 and C134, length of delay increased for each test session. Bird C120 was first tested on the 2-sec delay interval, and subsequent testing introduced 1-, 3-, 5-, and 4-sec delay intervals. After each bird had finished the series of delay tests, testing on both problems was repeated on the 1-sec delay interval to determine if performance levels on the delay tests were due to the delay intervals or to sequential effects.

The following procedure was used for presenting the delays: when the subject had completed the fixed ratio of 20 on the center key, the pattern which had been projected was re-

placed by an evenly illuminated field. Disappearance of this field was contingent upon the first response that occurred after a fixed interval of time. This interval defined the delay used on a particular session. Basically, length of delay was dependent upon the subjects responding on a fixed-interval schedule. The birds' own behavior, in addition to the externally programmed time contingency, determined the length of delay. Except for the procedure used for presenting delays, conditions during testing and during training were identical.

The birds were observed often during the test sessions through a wide-angle telescopic viewer and were visible at all times, except during the blackout periods. Special attention was paid to behavior during the fixed-interval periods which defined the delay intervals.

RESULTS

Figure 2 summarizes training results. Each set of bars represents the total number of sessions required by each subject to reach the criterion of learning on each separate and both of the two learning problems. In Fig. 2A and B, white bars represent consecutive sessions on the same problem; shaded bars represent alternation of the two problems on consecutive sessions. Bird C120 required 32 consecutive sessions to acquire the matching problem (Fig. 2, A) and four sessions (not counting days on the matching problem) of alternation of the two tasks to acquire the discrimination problem (Fig. 2, B). The same subject was performing both problems after a total of 50 sessions (Fig. 2, C). As many as 50 sessions were required because errors on the matching problem sometimes exceeded 10% of the total trials during the period when the alternate problem was acquired. Bird C134, which learned the two problems in the same sequence as Bird C120, required 24 sessions to acquire the matching problem and four sessions to do the discrimination problem; both problems were acquired after a total of 40 sessions. Bird C121 learned the discrimination problem in eight consecutive sessions (Fig. 2, B). The matching problem was learned in 25 sessions (not counting days on the discrimination problem) of alternation of the two problems (Fig. 2, A), and performance on both problems was at 90% or better after a total of 58 sessions (Fig. 2, C).

The training results indicate that the matching problem was the more difficult of the two tasks to acquire. This might have been due to the possibility that the matching problem represented a more complex situation than did the discrimination problem.

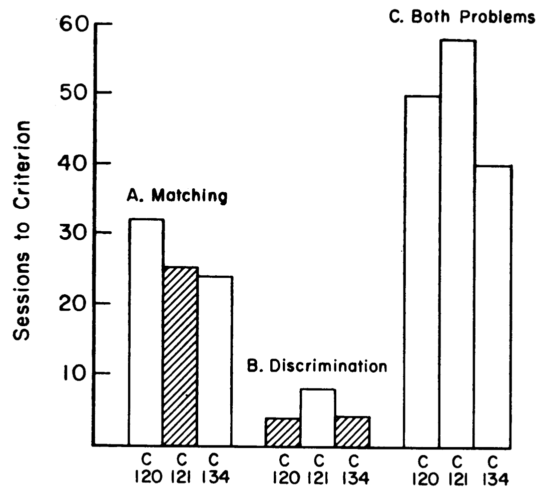

Fig. 2. Summary of training results. Bars represent number of sessions to criterion. In A and B, white bars indicate consecutive sessions on the same problem and shaded bars alternation of problems on consecutive sessions. In C, total sessions to final criterion are indicated.

Figure 3 shows the relationship between performance level and length of delay on the two problems. Data points represent "per cent correct" values. Delay performance on the discrimination problem is shown on the graphs as solid lines, and performance on the matching problem is indicated by broken lines. The 0-sec delay values were obtained by averaging the performance on the training sessions preceding each test session. The values for the repetition of the 1-sec delay performance are shown by the points to the extreme right on the graphs.

On the discrimination problem, all birds performed at a high degree of accuracy on the 1-sec delay interval. The individual delay functions were not of the same form; however, all can probably be characterized as being of a shallow, decreasing type. Each bird had a lower performance level on the delayed matching test than it had with the discrimination problem on the corresponding delay in-

tervals. Furthermore, on the matching problem, all subjects became steadily less accurate as the delay interval was lengthened.

The fact that repetition of the 1-sec delay test produced comparable results to the initial determination indicates that the performance decrements were due to the length of the delay intervals, not to the order of presentation of the delay tests.

The birds revealed no indication of overt orientation responses during the delay periods. Usually, they continued to peck the illuminated center key at a high rate during the fixed-interval periods which defined the

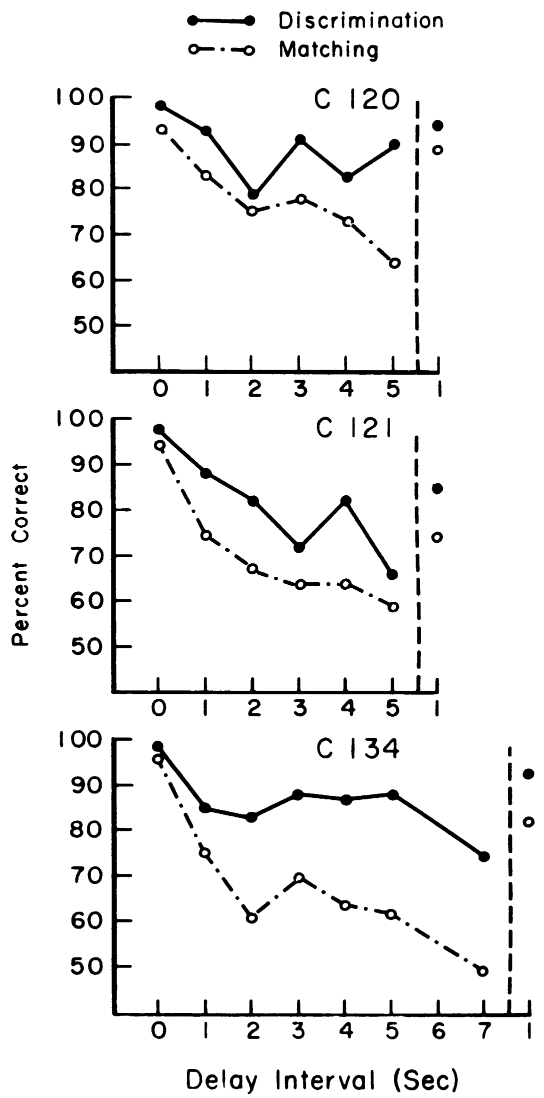

Fig. 3. Response accuracy as a function of delay interval. Points to the extreme right indicate repetition of 1-sec delay test.

magnitude of delays. An analysis of the temporal distribution of responses on the center key might have distinguished delay periods following presentation of different patterns, but no such data were collected.

DISCUSSION

The relation of delayed response performance to length of delay interval was found to vary according to the learning paradigm on which delay tests were based. In the delayed discrimination problem, the individual functions indicated only a slight effect of decreasing accuracy of performance with increasing delay intervals. In the matching problem, all three subjects showed a clear relationship between delayed matching performance and length of delay interval.

The conclusion that delayed matching performance was consistently poorer than delayed discrimination performance should perhaps be restricted to the particular patterns presented in the two tasks. The matching problem involving a vertical and horizontal bar might be more difficult than the discrimination problem involving an upright and inverted triangle, simply because of the patterns that were used. However, Hodos and Karten (1966) indicated that the discrimination between a vertical and horizontal bar is not more difficult for pigeons to acquire than the discrimination of triangles. Thus, the finding that delays affected performance on matching to a greater extent than they did discrimination performance does not seem to be invalidated by the possibility that bars should be more difficult to discriminate than triangles.

On the discrimination problem, the birds were confronted with a spatial task. They were rewarded for responding to the left key when one pattern had been presented and to the right when the alternate pattern was shown. The opportunity of reinforcing orientation responses during the delay period was probably diminished by using the fixed-interval schedule during this period.

Hearst's (1962) data on delayed alternation are of interest because the alternation paradigm also represents a spatial task. Hearst reported that most of the individual accuracy functions indicated best performance on the intermediate delay intervals (2 or 3 sec), and that the performance level was lower on the

extreme delay intervals (1 and 5 sec). The postural orientation which Hearst's birds developed after each key peck could account for this result. Such orientation probably represents temporal processes. On the shortest time interval in Hearst's experiment, the birds might not have had enough time to develop a definite orientation; on the longest delay interval, the birds might have turned away from the key toward which they had been oriented. Accordingly, the type of delay functions reported by Hearst may have been due to lack of control of behavior during the delay interval.

On the present matching problem, there is clear evidence of a decreasing accuracy function with lengthening of the delay interval. Matching-to-sample represents a nonspatial learning situation where the spatial aspect is present, but irrelevant. This indeed may be one of the factors that make matching problems so difficult to acquire. Studies of other types of delayed response (Hunter, 1913; Honzik, 1931) also suggest decreasing performance with increasing delays. The traditional experiments based delayed response experiments on three-choice, simultaneous discriminations. Such discriminations probably are difficult to acquire for most animals. It may appear as if decreasing accuracy functions with increasing delays are obtained in cases where delayed response experiments are based on complex learning paradigms.

Blough (1959) studied delayed matching in pigeons and reported relatively horizontal delay gradients for some of his subjects during portions of the test sessions. However, Blough often observed stereotyped movements during the delay intervals. These movements probably represent mediated responses which the birds developed, since no specific behavior was required of them during the delay. In the present experiment, the termination of the delay period was contingent upon a specific response; *i.e.*, a key peck. Therefore, the likelihood of adventitiously conditioning responses during the delay period was greatly reduced.

Blough reported that some of his birds developed different stereotyped movements during the delay periods, depending upon which of the two sample stimuli had been presented. Such stereotyped movements should be distinguished from orientation responses which can only be performed on spatial tasks. The conditioning of sample-specific responses could make it possible for Blough's birds to perform at a high level on the delayed matching problem without remembering the sample stimulus. This may explain the form of the delay functions for those of Blough's birds where stereotyped movements were observed.

In conclusion, it may be said that the type of problem, as well as length of delay, affects performance level in studies of delayed response. No statement concerning delay functions can be made without considering the paradigm on which different experiments have been based. This fact reflects the general ignorance as to which variables, besides length of delay, are important to performance level in delayed response experiments.

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