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# Delayed discriminations in the pigeon: The role of within-trial location of conditional cues

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**Four pigeons were trained in a delayed conditional discrimination in which color and line cues jointly indicated trial outcome. These were either combined in advance of a retention interval (RI) or separately presented before and after the RI. The former procedure resulted in less forgetting over the RI, the difference increasing with longer RIs. In a second study, the line cue was presented redundantly before and after the RI, and then selectively omitted from either temporal location during probe tests. In general, the results indicated that the birds relied upon the line as a cue to a greater extent when it was compounded with the color in advance of the RI than when it was presented after the RI. The data support an interpretation based on anticipatory processing in working memory, which leads to better retention than retrospective remembering.**

Many experiments on "short-term" memory in animals involve a conditional discrimination in which the information required for the correct response on each trial is provided by stimuli which are separated by an interval of time. A simple form of this problem was developed by Nelson and Wasserman (1978). Each trial began with a color as the sample, or initial, stimulus. This was followed by a retention interval (RI), during which no discriminative stimuli were presented. Then a test stimulus was shown. On positive trials, the test stimulus matched the initial color and the trial outcome was food, which was procured by responding to the test stimulus. On negative trials, the test stimulus did not match the initial stimulus, responses to the test stimulus had no effect, and the trial ended with a blackout. Discriminative responding was indicated by the proportion of total responses to the test stimulus on positive trials. Accuracy deteriorated markedly with increases in the RI.

With this method, Nelson and Wasserman systematically replicated the "memory decay function" typically obtained with the more familiar form of delayed true or conditional matching, in which two test stimuli are presented simultaneously (Blough, 1959; Roberts & Grant, 1976). This procedure requires a choice between the correct and incorrect comparison stimuli on each trial, while the presentation of a single test stimulus requires differential response rates on different trials.

Other methods for the study of short-term memory involve less complex discriminations in which information from temporally separated stimuli does not have to be combined for the performance of the correct response. Such methods are less well known, although the original studies by Hunter (1913) on the delayed response fall into this class. In several recent experiments, the necessary information regarding the correct response at the end of each trial has been provided at the time of the initial stimulus (Honig, 1978; Smith, 1967; Whalen, 1979). Memory functions obtained in this kind of experiment are generally less steep than those obtained from conditional discriminations in which information from the initial and the test stimuli has to be combined for a correct response.

Honig and Wasserman (1981) supported this conclusion with a direct comparison between a simple delayed discrimination (DD) and a delayed conditional discrimination (DCD). The DCD was similar to that of Nelson and Wasserman (1978). Trial outcome depended upon a conditional relationship between an initial color and a test line orientation. In the DD, the outcome of the trial was entirely determined by the initial color, and orientation of the test

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stimulus was irrelevant. Otherwise, the procedures were the same. Honig and Wasserman found that the memory functions obtained with the DD declined more slowly than those obtained with the DCD. One possible explanation of this finding is that, in the DD procedure, the pigeon needed only to remember the anticipated trial outcome, or the pattern of responding appropriate to that outcome. In the DCD, the subject could not determine the trial outcome until the test stimulus was presented, so the initial stimulus had to be remembered throughout the RI. If memory of the initial stimulus is lost more rapidly than the memory for the anticipated trial outcome (or the appropriate response pattern), then the difference in memory functions can be understood.

Presumably, a conditional discrimination is more difficult than a simple discrimination; indeed, Honig and Wasserman found that the former was acquired more slowly even without a retention interval. Problem difficulty was therefore confounded with the procedural difference of particular interest, namely the temporal locus of the information required to respond correctly to the test stimulus. The first experiment was designed to overcome this problem.

## EXPERIMENT 1

Pigeons were trained with two forms of the same conditional discrimination. In the conditional delayed discrimination, or CDD, two cues that conjointly signaled the outcome of the trial (and the correct response pattern) were presented together as the initial stimulus. Each trial began with green or red displayed on the response key together with vertical or horizontal lines. These are called combined-cues trials. Only two combinations, such as green-vertical and red-horizontal, were positive. They signaled that the trial would end with reinforcement. The other two (e.g., red-vertical and green-horizontal) signaled blackout as the trial outcome. Following a RI, a blue field was presented as the test stimulus. Response rates to the latter provided the index of discrimination; a high rate of responding should be observed only on positive trials.

The other form of the problem was the more traditional delayed conditional discrimination (DCD). Each trial began with green or red and ended (after the RI) with vertical or horizontal lines superimposed on the blue key as the test stimulus. These are called distributed-cues trials. Trial outcome was signaled by the same combinations of lines and colors as in the CDD, and the response measure was the same. (It may help the reader to note that the CDD involved *combined* cues, while the DCD involved *distributed* cues.)

We hoped that the two forms of the discrimination would be similar in difficulty, so that the pigeons would acquire them at about the same rate. Furthermore, we expected that, with short RIs, performance would be generally similar. However, we expected that, with longer RIs, performance would be superior in CDD trials, since the pigeons could anticipate appropriate test responding (and/or trial outcome) at the time of the initial stimulus. The DCD, on the other hand, required the memory of the initial stimulus during the RI. The general strategy involved the presentation of three different RIs during each session following acquisition. One was always 1 sec, which provided an indicator of the continuing mastery of the discrimination problem. The other RIs increased in the course of successive blocks of 36 sessions.

### Method

#### Subjects

The subjects were four experimentally naive White King pigeons obtained from the Palmetto Pigeon Plant in Sumter, S.C. They were maintained at 80% of their free-feeding weights. Toward the end of Experiment 1, they suffered from a calcium deficiency due to the use of crushed stone as grit. One bird (Subject 1397) was sacrificed for autopsy. The rest, who were then given oyster shell as grit, recovered from the deficiency before Experiment 2 was begun. It is not known to what extent the deficiency affected the results. However, the poorest performance was shown at the end of Experiment 1 by the bird that was sacrificed.

#### Apparatus

The apparatus was an operant behavior chamber, with interior dimensions of 34×36×30 cm. A single key was located 25 cm above the floor at the center of a curved metal panel at the front of the box. The feeder opening was 17 cm below the key. The key was about 2.5 cm in diameter. A Grason-Stadler in-line digital display projector (Pattern E4580-170) mounted behind the key provided discriminative stimuli. Sets of three parallel white lines, oriented vertically or horizontally, could be combined with fields of red, green, or blue. A PDP-8/e computer, running on the SuperSKED software system, controlled experimental contingencies.

#### Procedure

**Preliminary training**. The birds were magazine trained in two or three sessions in which grain was presented 40 times for 4 sec, at varying intervals, with a mean of 60 sec. The birds were then autoshaped to peck at the key. Keylight illumination of red, green, and blue, presented in random order, preceded each grain presentation. During the next few sessions, the birds were trained to complete short fixed ratios, pecking at each of these colors to obtain grain.

In the last phase of pretraining, the colors were presented in the sequences that would be used in the main training procedure. On each trial, the bird first completed a short FR by pecking at red or green, which were going to serve as the initial stimuli, and then completed a short FR by pecking at blue, which would be the test stimulus. The reward in each case was food, and trials were separated by 20 sec.

**Experimental trials**. Houselight illumination was white except during blackouts and during the RIs, when it was amber. After an ITI of 30 sec, each trial began with an initial stimulus of 5 sec. Responding to the initial stimulus was occasionally reinforced with 2-sec access to grain, without regard to the stimulus being displayed. A 20-sec random interval schedule was in effect. This was generated by assigning reinforcement to the first response occurring in each half-second, with a probability of .025. The timing of the initial stimulus was interrupted during reinforcements, and the keylight was turned off. The purpose of these reinforcements was to ensure similar rates of responding to all of the initial

Table 1
Trial Types and Retention Intervals for Experiment 1

| Initial Stimulus | Retention Interval (in Seconds) Phase 1 | Phase 2 | Phase 3 | Test Stimulus | Outcome |
|---|---|---|---|---|---|
| | | Combined Cues | | | |
| GV | 1,3,6 | 1,6,12 | 1,12,18 | B | Food |
| GH | 1,3,6 | 1,6,12 | 1,12,18 | B | BO |
| RV | 1,3,6 | 1,6,12 | 1,12,18 | B | BO |
| RH | 1,3,6 | 1,6,12 | 1,12,18 | B | Food |
| | | Distributed Cues | | | |
| G | 1,3,6 | 1,6,12 | 1,12,18 | BV | Food |
| G | 1,3,6 | 1,6,12 | 1,12,18 | BH | BO |
| R | 1,3,6 | 1,6,12 | 1,12,18 | BV | BO |
| R | 1,3,6 | 1,6,12 | 1,12,18 | BH | Food |

*Note—G = green, R = red, B = blue, V = vertical, H = horizontal; BO = blackout. Relationship of cues and outcomes was counterbalanced between subjects.*

stimuli, whether or not they signaled reinforcement at the end of the trial.

The initial stimulus was followed by the RI and the test stimulus. During the RI, the houselight was amber and no stimuli were displayed on the key. On a negative trial, the test stimulus was terminated after 5 sec and then followed by 3 sec of blackout. On a positive trial, the first response to the test stimulus following 5 sec produced grain for 3 sec. Only responses occurring during the first 5 sec of the test stimulus entered into the data analysis.

In a CDD (or combined-cues) trial, red or green was combined with a vertical or a horizontal white line during the initial stimulus, yielding four line-color combinations. Blue appeared on the key as the test stimulus. Each DCD (or distributed-cues) trial began with red or green on the key, and ended with a blue-vertical or blue-horizontal combination. For two birds, any trial containing both green and vertical, or red and horizontal, was positive, and ended with reinforcement. The other combinations were negative. For the other two birds, these contingencies were reversed.

**Discrimination ratio (DR).** CDD and DCD trials were analyzed separately for each RI in a session. Within each set of trials, the test stimulus signaled reinforcement on half of them. The DR for each set is the ratio of responses to the test stimulus on positive trials divided by responses to the test stimulus on positive and negative trials. A value of .50 indicates no discrimination, while a value of 1.00 represents a perfect discrimination with no responding to the test stimulus on negative trials.

**Sequence of training conditions.** The discriminations were first acquired with no RI. The criterion was a DR of at least .80 on each training problem, for 5 of 6 consecutive sessions. This criterion was reached slowly; the sessions required ranged from 26 to 51. A 1-sec RI was then introduced on all trials, and the same criterion was reattained. Regular training then began. Each session started with 8 warm-up trials in which only the 1-sec RI was used. The data from these trials were not used. The warm-up trials were followed by four regular training blocks of 24 trials each. Within each training block, 8 trials contained the short RI of 1 sec, 8 contained a medium RI, and 8 contained a long RI. Within each of these sets, four were CDD trials and four were DCD trials. Each subset of four trials contained the four possible combinations of the two colors and the two line orientations.

Three phases of regular training were run for 36 sessions each. In the first phase, the short, medium, and long RIs were 1, 3, and 6 sec, respectively. These values were increased to 1, 6, and 12 sec in the second phase, and to 1, 12, and 18 sec in the third phase. Table 1 summarizes the experimental procedures.

## Results

Initial acquisition of the conditional discrimination was generally more rapid with the DCD procedure. Table 2 presents the number of sessions required for each subject to reach three successive criteria: two consecutive sessions with overall DRs of .70, then of .75, and then of .80. It is readily seen that, in general, these criteria were more rapidly attained with the presentation of distributed cues. For Subjects 9543 and 1397, the difference was quite marked. Subject 1460 provides the only instance of a reversal of this pattern, at DR criteria of .75 and .80. The data were further examined by plotting the mean DRs from blocks of two consecutive sessions. These plots (not reproduced here) show that, after some initial sessions at the chance level, the DR improved for all subjects on the DCD problem while it stayed near .50 on the CDD problem for at least four sessions.

These data can be interpreted as follows: On distributed-cue trials, one of the conditional cues, namely the line, was presented during the test stimulus, immediately prior to the trial outcome of reinforcement or blackout. Thus, the subject was required to remember only the color during the 5 sec of the test stimulus in order to make the association between the conditional cues and the trial outcome. On combined-cue trials, however, both cues were presented prior to the test stimulus, which was blue on all trials. This form of the problem really involved a 5-sec retention interval prior to the trial outcome. It appears from the data that all of the subjects initially

Table 2
Training Sessions Required to Perform at Successive Criteria for Two Consecutive Sessions

| Subject | DR > .70 CDD | DR > .70 DCD | DR > .75 CDD | DR > .75 DCD | DR > .80 CDD | DR > .80 DCD |
|---|---|---|---|---|---|---|
| 1460 | 15 | 12 | 20 | 26 | 26 | 35 |
| 9543 | 29 | 15 | 29 | 15 | 38 | 16 |
| 1410 | 19 | 14 | 20 | 14 | 20 | 16 |
| 1397 | 30 | 16 | 31 | 17 | 31 | 17 |

acquired the problem with the distributed-cue trials, and then transferred their performance to the combined-cue trials.

The initial training phase was followed by sessions with an RI of 1 sec on all trials, in order to adapt the subjects to the RI when nothing was displayed on the key. The birds reattained satisfactory performance on both forms of the problem within 6 to 16 sessions. There was no reliable difference in performance on the CDD and the DCD forms of the discrimination.

The three principal phases of the experiment involved training with three different RIs presented during each session. The discrimination data were averaged for each of four blocks of nine sessions. These are shown in the four panels of Figure 1 for individual subjects. Data from the CDD trials are connected by unbroken lines, and those from the DCD, by broken lines. Different RI values are indicated by different symbols. The three major phases of training are presented in successive sections of each figure. We anticipated that the difference in performance on the CDD and the DCD would be small at the 1-sec RI. Therefore, the data indicated by circles (which represent the 1-sec RI) should be similar, whether the circles are connected by solid or by broken lines. With the longer RIs, the difference should increase in favor of the CDD.

Subject 9543 performed better on the DCD than on the CDD with the 1-sec RI. Results were somewhat mixed with longer RIs. At the 3-sec RI, DCD performance was again superior. At the 6-sec RI, the difference was less and decreased in the course of training, so that it was actually reversed by the end of the second phase. At the long RIs of 12 and 18 sec, performance of the DCD was close to chance, while it improved markedly on the CDD.

Subject 1460 showed the most consistent difference in favor of the CDD. This difference was observed for all RIs until the third phase, when the 1-sec DCD ratios rose to meet the 1-sec CDD ratios. The difference in performance generally increased as a function of the RI.

Subject 1410 generally performed better on the CDD problem. The difference with the 1-sec RI was small but consistent until the last phase of training, when performance deteriorated under all conditions except the 1-sec CDD. By the last block of nine sessions, performance on the 1-sec DCD reattained its previous level. CDD performance with the 12- and 18-sec RIs was also improving at the time, while the corresponding DCD data showed little change.

For Subject 1397, the difference on the 1-sec RI was always small. During Phase 1, the difference on the 6-sec RI was in favor of the CDD, and the same

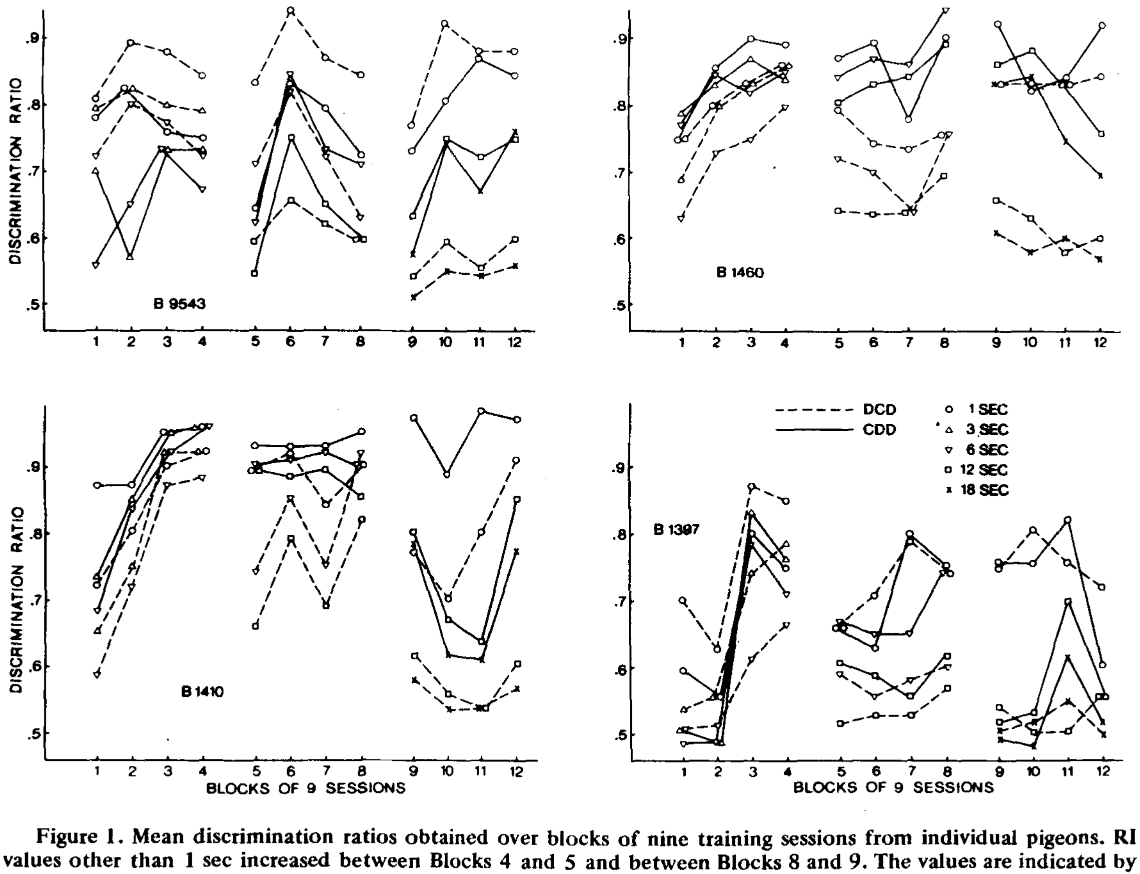


Figure 1. Mean discrimination ratios obtained over blocks of nine training sessions from individual pigeons. RI values other than 1 sec increased between Blocks 4 and 5 and between Blocks 8 and 9. The values are indicated by different symbols. Results from CDD trials are indicated by solid lines, and those from DCD trials, by dashed lines.

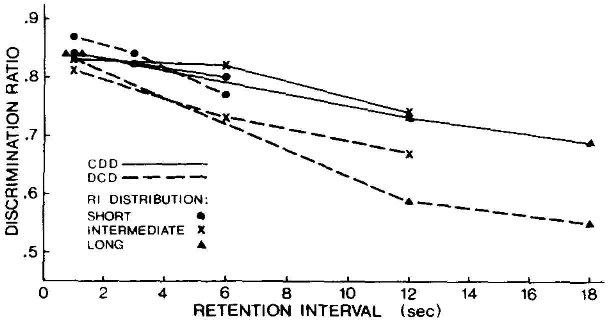


**Figure 2. Mean discrimination ratios obtained from all pigeons for the last block of nine training sessions under each distribution of RIs. The distributions are indicated by different symbols. Data from CDD trials are indicated by solid lines, and those from DCD trials, by broken lines.**

can be noted for Phase 2 for the 6- and 12-sec RIs. In Phase 3, performance at the medium and long RIs deteriorated generally. This subject developed a calcium deficiency during the last phase, and that may well have affected its performance.

Thus, all subjects demonstrated some of the similarities and differences between the two problems that we had anticipated, although no single subject did so in all respects. The findings are seen more clearly when they are averaged across birds and presented simply as a function of the RI. Figure 2 presents these data, taken from the last block of nine training sessions in each phase. There is little difference in performance at the 1- and 3-sec RIs. At 6 sec, a difference begins to appear. The CDD ratios from the long RI in Phase 1 and from the medium RI in Phase 2 are higher than the corresponding DCD ratios. This difference increases at 12 sec, which was the long RI in Phase 2 and the medium RI in Phase 3, and it is maintained at 18 sec, the long RI in Phase 3. This method of plotting the data supports the expectation that the difference between the CDD and the DCD would increase as a function of the RI, although inconsistencies are seen for individual subjects in Figure 1. (Replications of data points are quite good when the same RIs were used in different RI distributions, namely 1, 6, and 12 sec.)

### Discussion

In general, the results of this experiment conformed to our expectations. When cues were combined within the initial stimulus, within-trial memory was better (at delays of 6 sec or more) than when they were distributed. Since the DCD and CDD trials involved identical discriminative stimuli in the same conditional relationships, the difference in performance cannot readily be attributed to a difference in problem difficulty. Furthermore, the form of the discrimination which led to poorer within-trial memory was initially learned more quickly. Finally, there was no difference in performance with the 1-sec RI throughout the major portion of the study. The problems were equally difficult in the absence of a substantial memory requirement.

The two procedures permitted pigeons to adopt two different strategies in memory processing. Distributed cues required a "retrospective" strategy of remembering the initial stimulus throughout the RI. The combined initial presentation of the cues enabled them to anticipate the trial outcome, and to adopt a "prospective" strategy of remembering the anticipation. It is reasonable to suppose that if the subject could choose between different memory strategies, it would choose the anticipatory process, since this seems to result in better retention. This hypothesis was tested in the second experiment.

## EXPERIMENT 2

The general procedures were the same as in Experiment 1, but, during training, the line orientation cue was presented twice on each trial, once in conjunction with the initial color, and again as part of the test stimulus. Thus, the subject could use the line orientation information available at either temporal location. These are called "redundant-cue" trials. After this training, probe test trials were presented. On some, the line was presented only during the initial stimulus, resulting in a combined-cue trial, or CDD probe; on others, it was presented only during the test stimulus, resulting in a distributed-cue trial, or DCD probe. If the subject adopted a memory strategy based on the presentation of only the combined cues in training, then performance should not be disrupted during CDD probes. However, performance should be poor on DCD probes. The opposite result should be obtained if the subject adopted a strategy of retrospective remembering, using the presentation of the line during the test stimulus as the discriminative cue.

The general sequence of conditions was this: Three of the pigeons used in Experiment 1 were trained extensively on the redundant-cue procedure with RIs of 1 and 6 sec. Then, during distributed-cue test sessions, the line was omitted from the initial stimulus on one quarter of the trials, which turned these into DCD probes. After further retraining with redundant cues, the line was omitted from the test stimulus during combined-cue test sessions on one-quarter of the trials, which turned these into CDD probes. In the final phase, another series of baseline training sessions was followed by testing in which both DCD and CDD probes were presented in the same sessions. This is called the mixed-probes test.

## Method

### Subjects and Apparatus

Subjects 1410, 1460, and 9543 served in this study. The apparatus was the same as that used for Experiment 1. Before Experiment 2 began, the three birds were given several training and test procedures that involved the same conditional relations as in Experiment 1. These did not prove to be productive, and are not described here. In our view, the long-term effects of these procedures would not have been likely to influence the results of the present study.

### Procedure

The pigeons first received redundant-cue training. The contingencies governing color-line combinations and reinforcement were the same as before. Each session consisted of 96 regular redundant-cue trials following a block of 12 warm-up trials. Half of the regular trials contained an RI of 1 sec, while the remaining trials contained an RI of 6 sec; these are called 1-sec and 6-sec trials, respectively. On all trials, the line was presented both in combination with the initial color and with the blue test stimulus. The birds were trained for different numbers of sessions to bring each of them to a high level of performance.

Three test phases each consisted of 24 sessions and followed the initial redundant-cue training. The first test was the combined-cue test. In each session, 24 of the redundant-cue trials were replaced by combined-cue or CDD probe trials through the omission of the line during the test stimulus. Half of the test trials incorporated 1-sec delays and half incorporated 6-sec delays. The 24 test trials were distributed equally among the various possible combinations of line cues, color cues, and RIs. Normal reinforcement contingencies were in effect during the probe trials. Twelve further sessions of redundant-cue training were than followed by the distributed-cue test. The line was omitted from the IS on 24 probe trials, thus providing 24 distributed-cue, or DCD, trials. After 12 further redundant-cue training sessions, the third test phase (mixed-probes test) was administered. Twelve redundant-cue trials were replaced by CDD trials, and 12 redundant-cue trials were replaced by DCD trials during each session.

## Results

Figure 3 provides data for individual subjects summarized across six-session blocks of training and testing. Redundant-cue data are shown for the 12 sessions preceding the combined-cues test and for the 24 test sessions. CDD probe trial data are shown in the left-hand panels. There were only one-third as many probe trials as redundant-cue trials, and the data from the former are therefore likely to be more variable.

When the CDD test trials were introduced, performance was poorer than on the continuing redundant-cue trials. This could well have been due to a generalization decrement. Stimulus control of pecking to the test stimulus may well have been disrupted when the lines were suddenly removed from the key. Test-trial performance recovered within six sessions for Subject 1410 and within 12 sessions for Subject 9543. For Subject 1460, performance on the 6-sec delays recovered to a high level within six sessions, but this subject did poorly on the 1-sec delay throughout testing.

Test-trial performance was generally poorer with the short than with the long delay. This is, of course, opposite to the pattern normally observed and expected. The difference is not always large, but it is consistent; for Subject 1410, it is in favor of the long delay on 14 of the 16 sessions in which the DR was less than 1.00 on either problem ($p < .01$ by the binomial test). Subject 9543 performed better on 16 of the 24 sessions with the longer delay ($p < .08$), while Subject 1460 did better on 21 of the 24 sessions with the longer delay ($p < .001$). For the last subject, the difference in favor of the 6-sec RI trials was also observed on the redundant-cue trials. For the other birds, there was little effect of the RI during redundant-cue trials (Subject 1410), or it was in the opposite direction (Subject 9543).

Data from the DCD probe sessions and the preceding baseline training sessions are shown in the right-hand panels of Figure 3. The general pattern of findings is the same for all subjects. Omission of the line from the IS in the DCD trials had a marked effect on test performance. Discrimination was reduced with 1-sec RIs for Subjects 1410 and 9543 and with 6-sec RIs for all three subjects. There was some improvement in performance in the course of testing, but at the longer delay it did not reach the redundant-cue baseline for any subject. Performance was poorer with the 6-sec RI than with the 1-sec RI on at least 20 of 24 sessions for each subject ($p < .01$ by the binomial test). The performance decrement cannot in this case be attributed to a generalization decrement caused by a change in the test stimulus. The latter contained both line and color on DCD trials.

The mixed-probe test provided an opportunity to compare performance on CDD and on DCD test trials within the same sessions. The data from the test sessions were averaged for three-session blocks and inspected. There was little systematic change in performance following an initial improvement on test trials during the first block of three sessions. The data are therefore presented in Table 3 as means taken across the last 21 test sessions.

These data provide several comparisons of interest: (1) RI had little effect on redundant-cue trials; the mean DRs are .93 for both RIs. (2) Performance on 6-sec CDD probes was better than with 1-sec CDD probes, and it matched the accuracy obtained with redundant cues. (3) Performance with 1-sec DCD probes also matched baseline accuracy, and exceeded to some degree the performance with 6-sec DCD probes. The direction of this difference is the same as that obtained on the prior DCD probe test (see Figure 3), but the performance with 6-sec probes was much better.

These data replicate a curious interaction between test conditions and the RI that was observed in the first two phases of testing: When the initial line cue was omitted on DCD trials, performance was poorer at the longer delay, but on CDD trials, the discrimi-

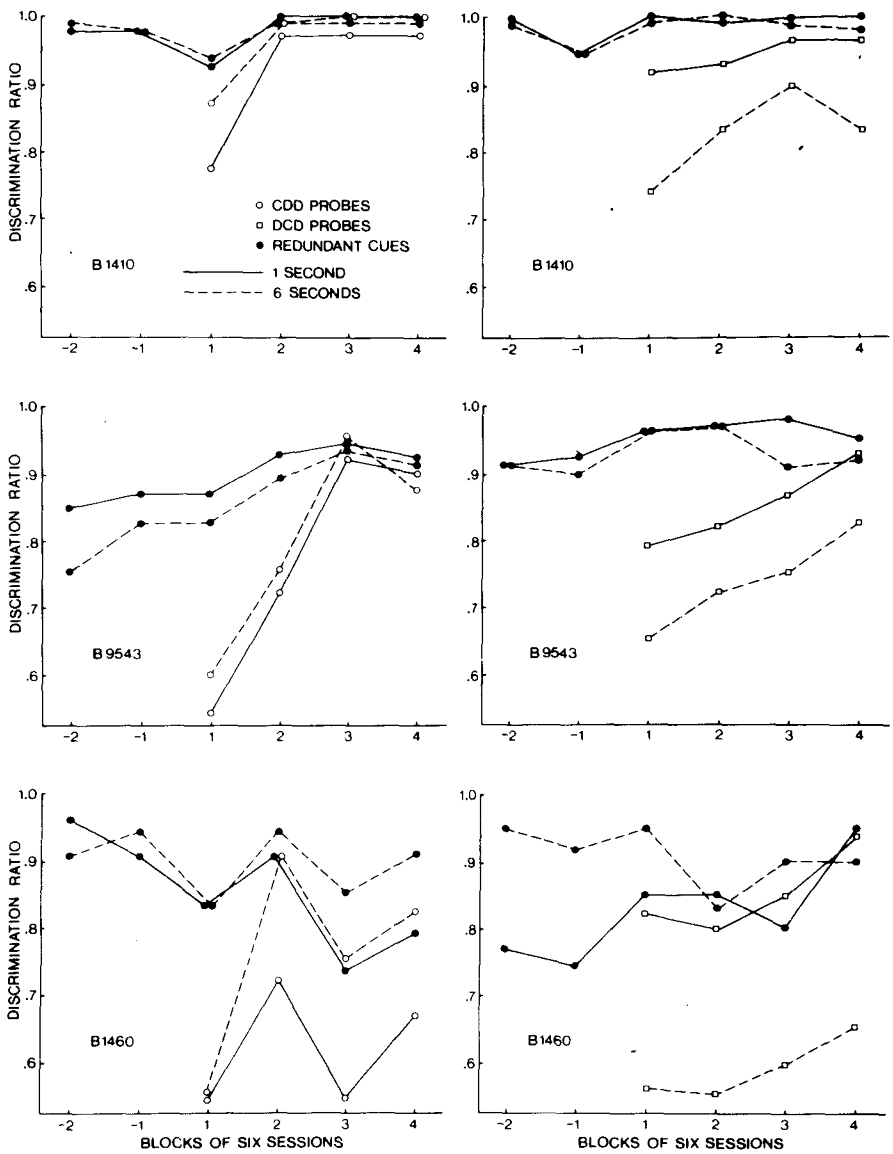


**Figure 3. Mean discrimination ratios obtained from six-session blocks of redundant-cue baseline trials (filled circles), CDD probes (left panels), and DCD probes (right panels) in Experiment 2. One- and 6-sec RIs are indicated by solid and dashed lines, respectively. Negative numbers on the abscissa indicate blocks of baseline training sessions preceding the introduction of probe trials.**

nation on the short delay was affected to a greater degree by omitting the line on the test stimulus. This effect would not seem to be due to the order in which the first two probe tests were given. And it does not depend on a generally weak level of performance. It is seen here in the context of a stable performance, when a high DR was obtained from most conditions, and when the two kinds of probe sessions were presented concurrently. It would seem, then, that this interaction is not an artifact, and deserves an attempt at explanation.

## Discussion

Performance on both kinds of probe trials was initially disrupted, then improved, and finally stabilized with a modest residual deficit. This deficit is seen on the longer delay with the DCD probes and on the shorter delay with the CDD probes. The findings are thus somewhat complex, and can be interpreted only with the help of a number of assumptions.

Extensive training with the redundant cues prior to testing may well have focused the subject's strategy

Table 3
Mean Discrimination Ratios From the Last 21 Test Sessions of Experiment 2

| Subject | Redundant Cues 1 | Redundant Cues 6 | CDD Probes 1 | CDD Probes 6 | DCD Probes 1 | DCD Probes 6 |
|---|---|---|---|---|---|---|
| 1410 | .98 | .94 | .94 | .95 | .94 | .89 |
| 1460 | .84 | .89 | .82 | .92 | .93 | .87 |
| 9543 | .98 | .96 | .78 | .94 | .94 | .92 |
| Mean | .93 | .93 | .85 | .94 | .94 | .89 |

*Note—1 = 1-sec RI; 6 = 6-sec RI.*

of remembering upon the anticipated trial outcome. When the line was removed from the initial stimulus on DCD probes, this precluded such a strategy, and forced the subject to remember the initial stimulus color. It may well have taken the birds some time to reacquire the "retentive" strategy of remembering the initial stimulus, particularly at the longer RI, at which the disruption was much more severe. The subjects recovered from the severe disruption with the DCD probes at different rates. By the time of the mixed-probe sessions, the residual deficit with the 6-sec RI was quite small. It is comparable to the difference between the DCD and the CDD trials with a 6-sec RI in Experiment 1. Thus, the results from the DCD probes can be explained in a manner consistent with that used for the prior results—retention of initial stimuli is quite good at short delays and then declines.

The interpretation of results from the CDD probes is more problematic. As indicated above, the initial severe disruption was probably due to a generalization decrement when the line was removed from the test stimulus. After the birds overcame this deficit, there was good performance with the long RI. This can presumably be attributed to anticipatory processing based upon the combined initial cues. However, two subjects still showed a modest residual deficit on the short-RI probes. This cannot be attributed to a residual generalization decrement, since no such decrement appeared with the 6-sec RI (see Table 3). If the subjects were using anticipatory processing on all probe trials, there is no reason to believe that they would do less well with a short RI than with a long RI. In Experiment 1, they did equally well on the CDD problem with 1- and 6-sec RIs (see Figure 2).

The possibility remains that during redundant-cue training these birds used a retrospective memory process for the short RI. They would have needed to remember only the color, as the line orientation was provided with the test stimulus. In the short-RI test trials, they would have had to remember both the color and the line orientation. This would explain why the performance was poorer than on the 1-sec DCD probe trials (which presumably also required a retrospective process): In the latter case, the subjects needed to remember only the color, as the line was presented as part of the test stimulus. Possibly, the subjects were "organizing" a prospective strategy during the first second or so of the RI. This may have taken the form of initiating a pattern of mediating behavior. Clearly, this explanation is ad hoc, as there is only indirect evidence to support it.

## GENERAL DISCUSSION

Experiment 1 provides a systematic replication of the experiments of Honig and Wasserman (1981), who compared memory functions from simple delayed discrimination (DD) training and a DCD procedure. A comparison of our results with Experiment 2 from that study is particularly appropriate, since both experiments involved a within-subjects comparison of performance on the DD (or CDD) and DCD problems. The similarity of the forgetting curves is impressive. The DD function from Honig and Wasserman is slightly higher than the present CDD function, perhaps because the DD is a simple discrimination rather than a conditional one. The two DCD functions are remarkably similar. For example, the discrimination ratios were .84 at the 0-sec RI in Honig and Wasserman and .84 at the 1-sec RI in the present study. At 10 sec, they were .63 in Honig and Wasserman, and at 12 sec they were .63 in the present study. At 18 sec they are estimated at .55 in Honig and Wasserman, while we obtained the same value. It should be noted that Honig and Wasserman's Experiment 2 was run at the University of Iowa, while the present work was conducted at Dalhousie University.

In accordance with the previous interpretation of the Honig and Wasserman study, we suggest that the conjunction of cues in the initial stimulus of our experiment enabled the subjects to adopt an anticipatory strategy with respect to trial outcome. This strategy is less subject to forgetting than the retrospective strategy required by the separation of cues in the DCD procedure. Yet we cannot specify the nature of the anticipatory strategy. The pigeons may have anticipated the appropriate pattern of responding and possibly have engaged in differential mediating behavior. They may have developed an expectancy of reward or no reward based upon the initial stimuli; this could have served as a differential cue at the time of the test stimulus. Recent work by Peterson and his associates (Peterson & Trapold, 1980; Peterson, Wheeler, & Trapold, 1980) demonstrates that such outcome expectancies enhance working memory. In some of their experiments, one of the differential outcomes is actually no reward with the opportunity to advance to the next trial. (Errors are followed by the repetition of the trial.) Thus, it is not unreasonable to suppose that the expectation of no reward can serve as a cue in the present experiments, which will suppress responding at the time of the test stimulus. It is precisely this suppression which is responsible for high discrimination ratios.

The initial stimulus in the DCD problem may generate mediating activity as well. Yet the cues from such an activity still have to be combined with differential cues from the test stimuli to obtain correct performance. This is not the case with the CDD procedure, in which the test stimulus is always a blue field. Furthermore, such mediation cannot take the form of an outcome expectancy, since the necessary information regarding the outcome is not available until the time of the test stimulus. It is also possible for pigeons in the DCD problem to develop an "instructional code" regarding the end of the trial, such as "if vertical, peck; if horizontal, don't peck." Such a process would be prospective rather than retrospective (see Farthing, Wagner, Gilmour, & Waxman, 1977; Honig & Thompson, 1982). However, such a code would be more complex than the simple anticipation that suffices for the CDD procedure. Thus, it may be forgotten more quickly.

In Experiment 2, we tested a prediction derived from our account of differential performance on CDD and DCD trials. The conditional line cues were presented with the initial and the test stimuli. The subjects could therefore anticipate the trial outcome from the former, but need not have done so, since memory of stimulus information from the initial cue would be sufficient for correct responding to the test stimulus. The results from Experiment 1 suggested that the anticipatory strategy was easier. Therefore, we expected poorer performance when the line was omitted from the initial stimulus on DCD probes, than from the test stimulus on CDD probes. This result was obtained at the 6-sec RI once responding had stabilized with both test procedures. There was, however, a modest deficit on CDD trials with a 1-sec delay. We suggest that this was due to the use of retrospective remembering of the compound stimulus at this delay, with a relatively poor memory of the line orientation. However, there is no other, independent evidence of the use of retrospective and prospective memory processing within the same trial.

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