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THE EFFECTS OF CUING RETENTION INTERVAL LENGTH ON PIGEON SHORT-TERM MEMORY

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BY

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

EDMONTON, ALBERTA

FALL, 1986

ISBN 0-315-32386-8

THE UNIVERSITY OF ALBERTA

RELEASE FORM

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TITLE OF THESIS: The effects of cuing retention interval length on pigeon short-term memory.

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1986

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECTS OF CUING RETENTION INTERVAL LENGTH ON PIGEON SHORT-TERM MEMORY submitted by Suzanne E. MacDonald in partial fufillment of the requirements for the degree of Master of Science.

(Supervisor)

Date: May 15, 1986

Abstract

A series of five experiments examined the effect of cuing retention interval length on pigeon's delayed matching-to-sample performance. The first experiment was basically a replication of Experiment 2 in Wasserman, Grosch and Nevin's (1982) study. The effects on performance of cues correlated with retention interval length were assessed by miscuing on some trials. Responding to the sample/cue compound and during the retention interval was also recorded. Consistent with earlier research, it was found that presenting a "long" cue before a short delay significantly reduced matching accuracy, relative to trials on which a "short" cue preceded the short delay. In addition, birds pecked the long cue at a much lower rate than they did the short cue.

The second and third experiments tested the differential attention account. The differential attention account of Wasserman et al. (see also Honig and Dodd, 1986) suggests that informative cues presented in compound with the sample stimulus may only affect memory of the sample to the extent that they control the amount of attention or "encoding time" given to it. In Experiment 2, the informative cues were moved into the retention interval and accuracy on correctly and incorrectly cued trials was compared. Because the cues were presented only during the delay interval, they could not influence attention to the sample. In Experiment 3, a

within-subject comparison of the relative effectiveness of cues presented in compound with the sample versus cues presented only in the retention interval was performed. The results of both experiments revealed no support for the notion that cuing would be effective only when the cues and sample stimuli are compounded.

Given the failure of Experiments 2 and 3 to support the differential attention account, Experiments 4 and 5 tested an alternative account emphasizing processes of rehearsal. According to this account, the presentation of a "long" cue may terminate or decrease rehearsal of sample information, resulting in reduced matching accuracy at the time of test. Experiment 4 involved a manipulation of retention interval duration. Long and short cues were presented on an equal number of 1, 3 and 8 s delay trials. If presentation of a "long" cue decreases rehearsal or processing of sample information, the rate of forgetting should be faster on long-cued trials than on short-cued trials. In Experiment 5, the long cue was presented at either the beginning or the end of the retention interval. If presentation of a long cue terminates rehearsal of the information contained in the sample stimulus, miscuing at the beginning of the retention interval should result in reduced matching accuracy relative to trials on which the miscuing occurs at the end of the retention interval. The results of both experiments were inconsistent with the rehearsal account.

It was concluded that cues associated with a particular retention interval length influence neither sample processing (attention or encoding) nor postsample processing (rehearsal). It appears such cues modulate accuracy by influencing test responding independently of memory. One possibility is that a cue associated with a long retention interval may depress accuracy by reducing the motivation to respond correctly at testing rather than by influencing the strength of the sample memory. The implications of this interpretation were discussed.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Doug Grant for his unfailing support, encouragement and advice throughout this project. Thanks are also due to Dr. Don Heth and Dr. Fred Morrison for serving on my committee, and for their helpful comments.

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I. Introduction

The delayed matching-to-sample procedure has been used extensively in studies of pigeon short-term retention (e.g., Grant, 1981; Maki, 1979; Roberts & Grant, 1976). A standard delayed matching trial involves the presentation of a sample stimulus (usually colored fields) for a fixed duration. The sample is followed by a retention or delay interval which may vary in length (usually between zero and ten seconds). Following the retention interval, a test is presented. In the two choice version of matching, the test involves presentation of two comparison stimuli, one of which matches the sample and one of which does not. A response to the correct (matching) comparison results in reinforcement, whereas an incorrect response results in a brief blackout period. In the successive or go/no go version of matching, the test involves presentation of a single comparison stimulus. If the comparison matches the sample, then the first response after 5 seconds is reinforced. If the comparison does not match the sample stimulus, the comparison terminates in nonreinforcement after 5 seconds (e.g., Nelson & Wasserman, 1978). In both versions, an intertrial interval follows each trial outcome. A typical session consists of 50-100 trials, with each sample stimulus presented equally often, and position of the correct comparison stimulus balanced within each sample type.

Most studies of pigeon short-term memory use two or more different retention interval values, scheduled randomly throughout each daily session. Typically, matching accuracy decreases as the retention interval is lengthened. In a recent series of experiments conducted by Wasserman, Grosch and Nevin (1982) the effect of signaling the length of an upcoming retention interval was studied in a successive matching task. One group of birds received cues that were reliably correlated with retention interval length; in a second group, cues and retention interval length were uncorrelated. In both groups the cues (line orientations) were presented in conjunction with the sample stimulus (colored fields). Wasserman et al. suggested that signaling the duration of an upcoming retention interval might facilitate retention of the sample stimulus over the interval period, and would thus lead to more accurate performance, especially at long delay values, in birds receiving correlated cues.

However, results from their first experiment showed that only matching accuracy at the short delay (1 s) was facilitated by signaling retention interval length. Matching accuracy at the long delay (5 s) was lower than that for birds which were trained with uncorrelated cues. The retention function was thus steeper for the birds trained with correlated cues. They also found that the birds exposed to correlated cues pecked the sample at a higher rate when the short retention interval cue was present than when the long retention interval cue was present. Wasserman et al. suggested that the birds thus had greater exposure to the sample stimulus on short-cued trials and that this increased sample exposure led to increased test accuracy. They suggested that the reduced accuracy on long-cued trials occurred because the rate of responding to the long cue/sample compound was not as high as that to the short cue/sample compound. The birds thus had less exposure to the sample stimulus on long-cued trials, and this decreased sample exposure led to decreased test accuracy.

In their second experiment, miscued trials were employed on which the "short cue" preceded a long delay, and the "long cue" preceded a short delay. They found that accuracy at both delays was higher when preceded by the "short" cue than when preceded by the "long" cue. Again, the birds pecked the sample stimulus more on short-cued trials than on long-cued trials. This was true on both correctly cued and miscued trials. These results were taken as further evidence for a differential attention account.

Overall, differential attention to the sample stimulus was suggested as the mechanism whereby cues signaling retention interval length modulate performance. Wasserman et al. proposed that the informative cues modulate performance by differentially eliciting keypecking (and presumably attention) during the sample stimulus. In particular, rate of responding to the sample is enhanced by presentation of a "short" cue and reduced by presentation of a "long" cue.

In research conducted independently of that of Wasserman et al., Dodd and Honig (1981; cited in Honig & Dodd, 1986) also explored the effect of cuing retention interval length on matching accuracy. They employed a delayed discrimination task. Sample stimuli were horizontal and vertical lines; the comparison stimulus was a white field. Responding to the comparison was reinforced after one line orientation but not after the other. Informative cues were colored fields, and the cues were combined with the sample stimulus. In their initial study, two of the cues signaled the duration of an upcoming retention interval (either short or long), while a third cue provided no differential information. Miscued probe trials resulted in a significant reduction in discrimination on long-cued short delay trials, and a slight (but non-significant) increase in discrimination on short-cued long delay trials. A systematic replication using only correlated cues again revealed a significant decrease in discrimination on miscued short delay trials, and showed no effect of miscuing long delay trials. Like Wasserman et al. (1982), Honig and Dodd (1986) suggested that pigeons may pay more attention to the sample stimulus on short-cued trials, and this differential attention may explain the cuing effect.

The experiments reported here explored further the cuing phenomenon discovered by Wasserman, Grosch and Nevin (1982) and Dodd and Honig (1981, cited in Honig & Dodd, 1986). In particular, interest focused on the mechanism whereby retention interval cues modulate delayed matching accuracy. Although the data of both Wasserman et al. and Dodd and Honig are consistent with the differential sample attention account, neither study included a direct test of that interpretation. Such a test was conducted as part of the present investigation and is reported as Experiments 2 and 3. The results of those experiments failed to support the differential sample attention account, and Experiments 4 and 5 were conducted to assess alternative accounts. Experiment 1 of the present series replicated the finding of Wasserman et al. (Experiment 2) and Dodd & Honig that miscuing retention interval length tends to decrease accuracy at the short delay and to increase accuracy at the long delay.

II. Experiment 1

The first experiment was designed to replicate the miscuing effect reported by Wasserman et al. (1982) and Dodd and Honig (1981). Wasserman et al. used a successive matching task; Dodd and Honig used a delayed simple discrimination. All the experiments reported here used a delayed matching-to-sample "choice" procedure with colors as sample and comparison stimuli. Informative cues were either line or shape stimuli. Birds were trained with correlated cues only, and the effects of these cues on performance was assessed by miscuing some trials during test sessions. Two groups of birds were trained and tested. Initial data from Group A (White King) birds was somewhat different than that obtained by Wasserman et al using Silver King pigeons. Therefore, Group B (Silver King) birds were run as a replication to ensure that the obtained results were reliable.

Method

Subjects. Group A consisted of six experimentally naive adult White King pigeons. Group B consisted of five experimentally naive adult Silver King pigeons. All birds were reduced to and maintained at 80% of their free-feeding weight by restricted feeding. The birds were individually housed under 24-h illumination, with water and grit always available in the home cages.

Apparatus. Training and testing was conducted in identical modular test chambers. Three pecking keys were mounted in a horizontal row, 20 cm above the grid floor. An Industrial Electronic Engineer, Inc. (IEE) in-line projector mounted behind each key was used to project stimuli onto the pecking key. The stimuli employed in the experiments were a black dot on a white ground, a white horizontal or vertical line on a black ground, a white triangle or "X" on a black ground and red and green fields. A grain feeder was mounted below the center pecking key. A 28-v house light was mounted above the center pecking key. The house light was positioned so that the light emitted was directed toward the ceiling of the chamber. The light was illuminated continuously, except for brief blackout periods following incorrect responses. The test chamber was inside a sound and light-attenuating enclosure. Masking noise was provided by an exhaust fan in the enclosure, and by white noise delivered through a speaker in the testing room.

The presentation of events within the chambers and the recording of data was controlled using microcomputers.

Procedure. Training for both groups of birds was identical. The birds were first magazine trained, and then autoshaped to the black dot/white ground stimulus, which served as the preparatory stimulus during training and testing. The birds then began training on a simultaneous matching-to-sample (SMTS) procedure using red and green fields as sample and test stimuli.

Each trial began with the illumination of the center key by the preparatory stimulus. A single peck to this stimulus terminated it, and resulted in immediate sample presentation. If the bird did not respond within five seconds, the preparatory stimulus was extinguished and the sample was presented. After the sample stimulus had been presented for 5 s, independent of responding, the two side pecking keys were illuminated by the test stimuli (red and green fields). A single response to the correct test stimulus (red sample-red test or green sample-green test) resulted in reinforcement- a 2.5 s period of grain access. Incorrect responses resulted in a 2.5 s blackout period during which the houselight was extinguished. Each trial was followed by a 20 s intertrial interval during which all pecking keys were darkened. The houselight remained on during this interval.

A session consisted of eighty trials, with each sample occurring forty times. Position of the matching test stimulus was balanced for each sample type.

A correction procedure was in effect for the early training sessions, to speed acquisition of matching-to-sample. In this procedure, an incorrect match and subsequent blackout were followed by re-presentation of the sample and test stimuli from the trial. A correct match resulted in reinforcement, and ended the trial. An incorrect match again resulted in a blackout, and re-presentation of the sample and test stimuli. A trial did not end until a correct match was made.

After acquisition of matching-to-sample, the correction procedure was discontinued and the usual matching-to-sample procedure (with no correction for error) began.

SMTS training was followed by zero-delay matching, in which the sample stimulus was extinguished immediately before presentation of test stimuli. Following acquisition of zero-delay MTS, two retention intervals were introduced. Delays were short initially, and were gradually increased over sessions to the final values of 1 and 5 s. Phase 1 of preliminary training lasted for a total of 136 sessions for the birds in Group A. Preliminary training lasted only 68 sessions for the birds in Group B, because they acquired the matching problem more quickly than the Group A birds.

When performance stabilized on the delayed matching task at both short (1 s) and long (5 s) retention intervals, correlated cues were introduced. For half of the birds in each Group, these cues were a horizontal line (signaling a short retention interval) and a vertical line (signaling a long retention interval). For the remaining birds in each Group, the correlated cues were a triangle stimulus (short retention interval) and a "X" (long retention interval). As Figure 1 illustrates, the cues were presented in compound with the sample during the last two seconds of the sample stimulus presentation. The cues remained illuminated for the first second of the retention interval. Training with the correlated cues continued for a total of 44 sessions for both Groups.

Experiment 1 consisted of baseline and test sessions. Baseline sessions contained 80 trials, and were identical with those of training. Test sessions consisted of 96 trials. The majority of the trials (64) were baseline trials. Sixteen of the test session trials were miscued. On these trials a "short" cue was presented before a long delay (8 trials per session) and a "long" cue was presented before a short delay (8 trials per session). Data from miscued trials was compared with that from an equal number of appropriately cued trials. Testing continued for 24 sessions, with baseline (12 sessions) and test sessions (12 sessions) occurring on alternate days.

Results

The mean percentage of correct responses on correctly and incorrectly cued trials as a function of delay for both Groups is illustrated in Figure 2. The percentage of correct responses declined from the 1 to 5 second delay on correctly cued trials in both Groups. This decrease was not evident on

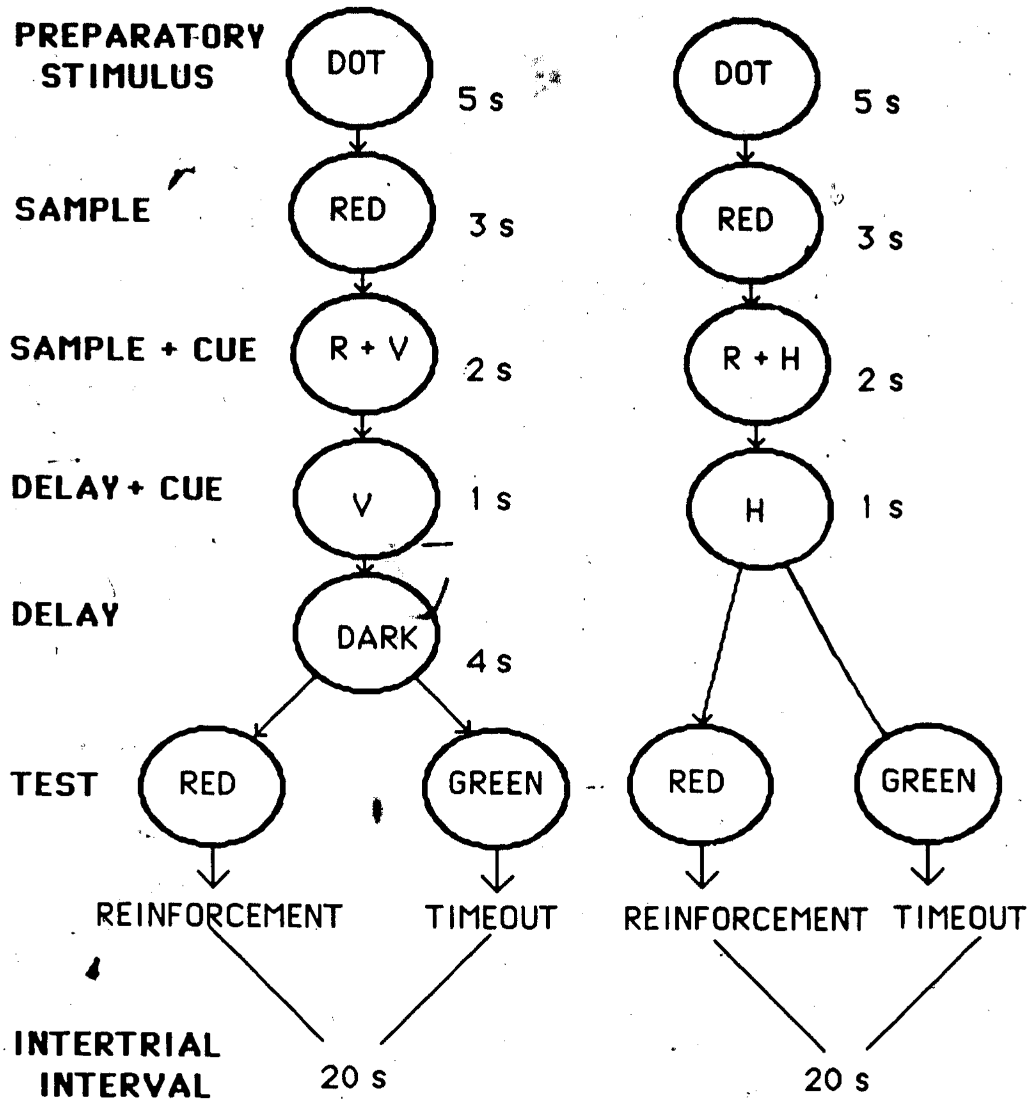
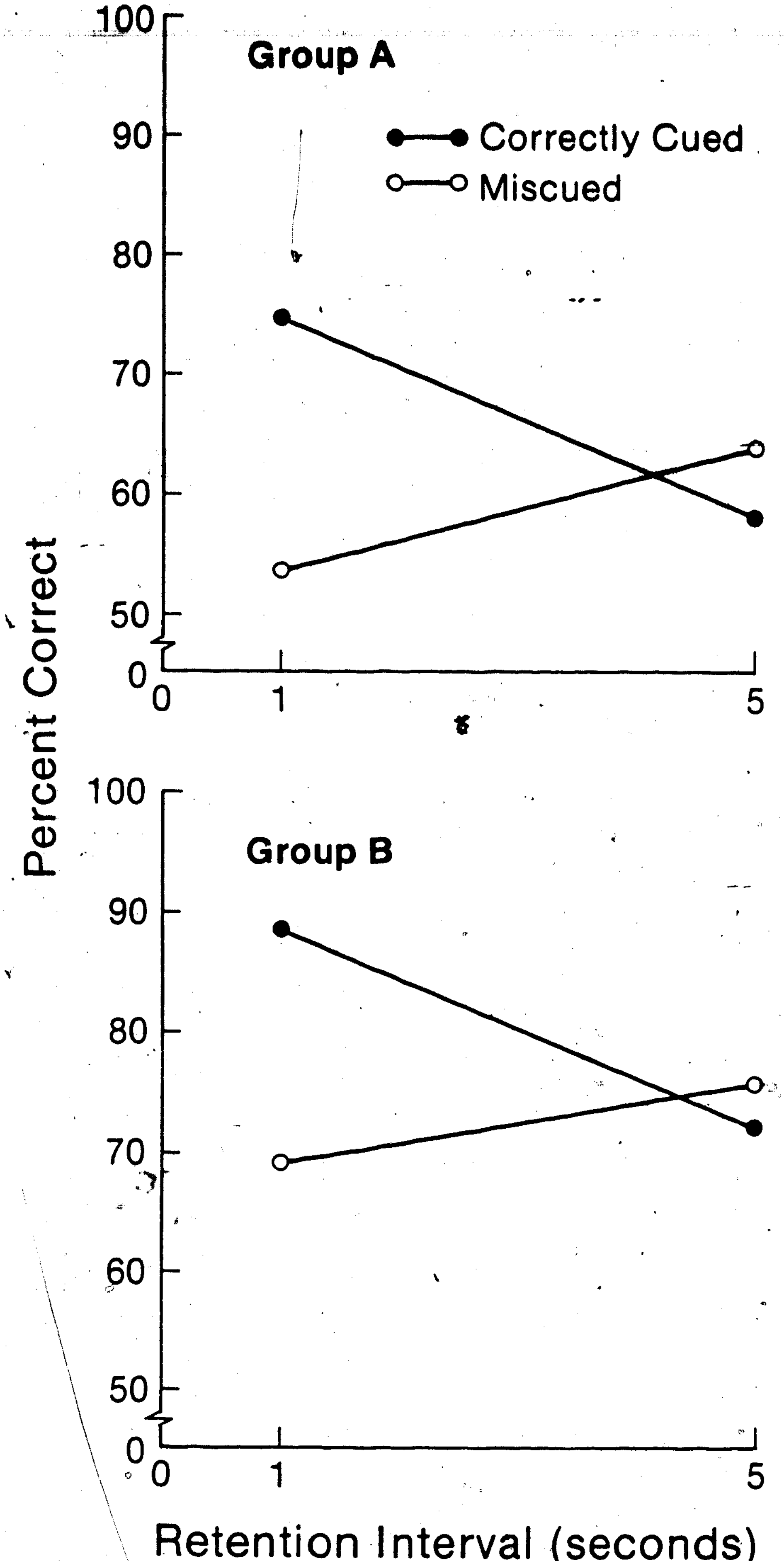


Figure 1. Illustration of signaled retention interval DMTS. The trials shown here involve a red sample. Substituting green for red represents a trial involving a green sample. The cues shown here are lines, which were the informative cues for half of the birds ("V" = vertical line; "H" = horizontal line). Substituting a triangle for the horizontal line and a "X" for the vertical line illustrates the cues for the remaining birds.

Figure 2. Mean percentage of correct responses on correctly cued and miscued trials as a function of retention interval for each group in Experiment 1.


Group A
Correctly Cued
Miscued
Group B
Percent Correct
Retention Interval (seconds)
100
90
80
70
60
50
0
0
1
5

incorrectly cued trials. Averaged over groups, matching accuracy was 20.1% percentage points lower on long-cued short delay trials than on short-cued short delay trials. At the long delay, matching accuracy was 4.6% percentage points higher on short-cued trials than on long-cued trials.

A three-factor analysis of variance was performed on the data for each Group. Factors were Blocks of eight sessions, Trial type (correctly vs. incorrectly cued) and Delay. The only significant main effect in Group A was trial type, $F(1,5) = 8.42$, $p<.05$. The only significant main effect in Group B was delay, $F(1,4) = 8.93$, $p<.05$. The Trial type by Delay interaction was highly reliable in both Groups of birds (Group A: $F(1,5) = 31.05$, $p<.01$; Group B: $F(1,4) = 29.26$, $p<.01$). Presentation of the long retention interval cue decreased matching accuracy significantly at the short delay (Group A: $t(5) = 3.88$, $p<.01$; Group B: $t(4) = 2.64$, $p<.05$) as compared to correctly cued trials. Presentation of the short delay cue produced a slight but non-significant increase in matching accuracy at the long delay (Group A: $t(5) = 1.21$, $p>.05$; Group B: $t(4) = .38$, $p>.05$). No other interactions approached significance.

Keypecking during the sample and retention interval was recorded for both Groups. Data was collapsed over groups and blocks of sessions. Rate of sample responding was higher in the presence of the "short" cue (2.19 pecks/s) than in the presence of the "long" cue (0.61 pecks/s). Also, rate of retention interval responding was higher on "short" cued trials (1.7 pecks/s) than on "long" cued trials (0.72 pecks/s). One way ANOVA's revealed that both effects were reliable, $F(1, 10) = 15.53$, $p<.01$, for sample response rates and $F(1,10) = 9.01$, $p<.01$ for retention interval response rates.

Discussion

These findings are similar to those of Dodd and Honig (1981, reported in Honig & Dodd, 1986). They used a delayed simple discrimination procedure, with line stimuli as samples and colors as informative cues. Miscuing resulted in significantly poorer discrimination ratios on short trials (long cue) in comparison to correctly cued trials. Discrimination ratios on long delay trials (short cue) were slightly better than correctly cued trials, although the difference was not statistically significant. A systematic replication revealed a similar reduction of discrimination on short delay trials following the long cue.

Both Dodd and Honig's (1981) results and the results of the present experiment failed to reveal enhanced matching accuracy on long delay miscued trials. Wasserman et al. (1982) found significantly better discrimination ratios on miscued long delay trials than on correctly cued long delay trials (Expt. 2). Wasserman et al. employed a successive matching-to-sample procedure, and their results may be related to the use of this procedure. It appears that for the choice DMTS (present Experiment 1) and delayed simple discrimination procedures (Dodd & Honig, 1981, cited in Honig & Dodd, 1986) the primary cuing effect is one of decreased matching accuracy on long-cued short delay trials, relative to correctly cued trials. Presentation of the "short" cue does not significantly enhance matching accuracy on long delay trials, relative to correctly cued trials.

As in the Wasserman et al. (1982) study, pigeons in the present experiment pecked the sample stimulus at a higher rate when the short retention interval cue was present than when the long interval cue was present. This finding is consistent with the suggestion of Wasserman et al. and Dodd and Honig that informative cues may influence accuracy by modulating attention to the sample stimulus. The second experiment tested this hypothesis directly.

III. Experiment 2

Wasserman et al. (1982) and Dodd and Honig (1981) suggested that the differential performance observed with short and long cued retention intervals was probably due to differential attention to the sample stimulus on short and long cued trials. The informative cues may affect matching accuracy simply by controlling the amount of attention or "encoding" given to the sample stimulus. Presenting the informative cues during the retention interval only ensures that the cues can not affect sample responding. If the cuing effect occurs when post-sample cues are presented, the effect can not be attributed to differential attention to the sample stimulus. The informative cues were moved into the retention interval in Experiment 2 to test the differential attention hypothesis directly. The procedure was identical with the previous experiment, but the cues were presented only during the retention interval rather than in compound with the sample.

Method

Subjects and Apparatus. The subjects for this Experiment were the six Group A birds. The apparatus was the same as that described for Experiment 1.

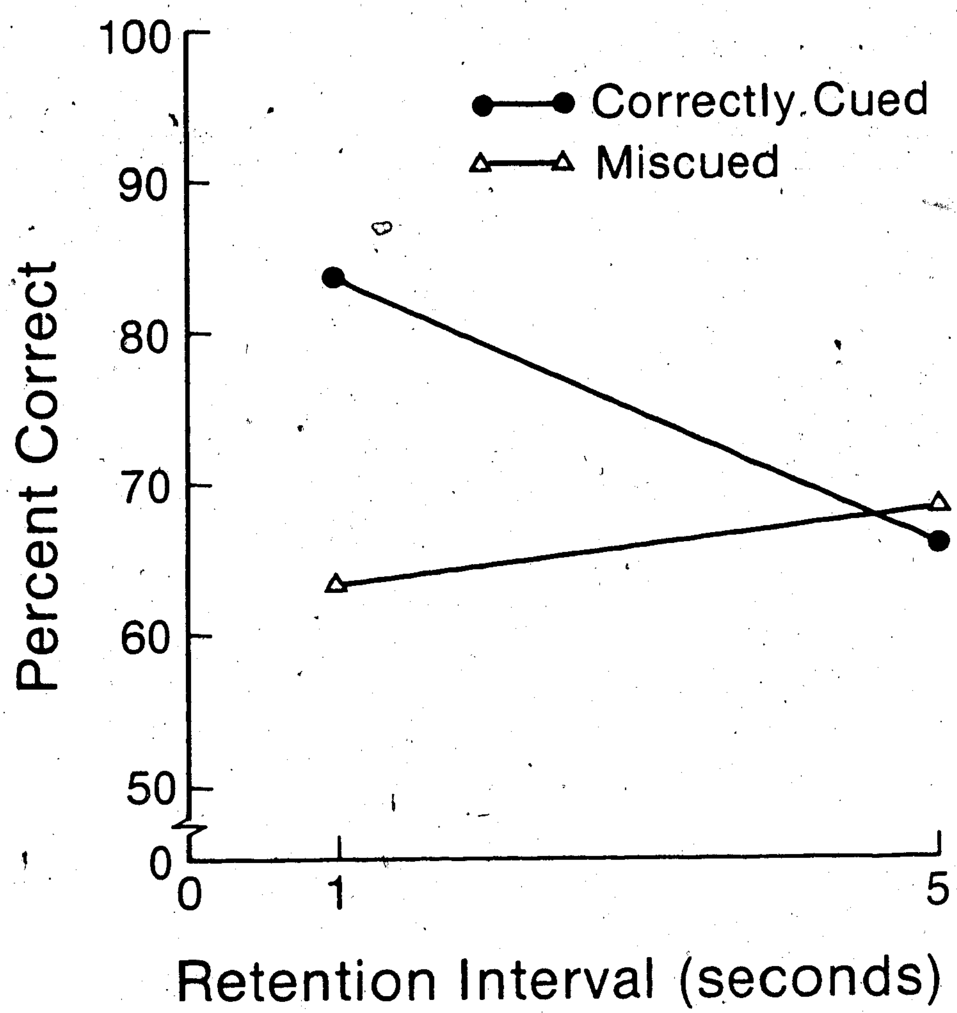
Procedure. Birds were returned to baseline training for 16 sessions after Experiment 1, prior to Experiment 2. Experiment 2 consisted of baseline and test sessions. The baseline sessions were identical with those of Experiment 1 and those of training (shown in Figure 1). Test sessions were identical to those of Experiment 1, except the informative cues were not presented in compound with the sample stimulus on cued and miscued trials. The cues were presented immediately after sample termination, and remained illuminated during the first 1 s of the retention interval. Baseline and test sessions occurred on alternate days. A total of 8 baseline and 8 test sessions were run.

Results

The mean percentage of correct responses on correctly and incorrectly cued trials is shown in Figure 3. Clearly, the results of Experiment 2 are similar to those of Experiment 1 (see top panel, Figure 2). In Experiment 1, there was a decrease of 20.1 percentage points at the short delay on miscued trials, relative to correctly cued trials. This decrease was 20.5 percentage points in the present experiment. Accuracy increased 4.6 percentage points at the long delay on miscued trials, relative to correctly cued trials in Experiment 1; this increase was 1.8 percentage points in the present experiment. As in Experiment 1, the retention function in the present experiment was markedly "flattened" on incorrectly cued trials.

A 3-factor analysis of variance was performed on the data. The three factors were Blocks, Trial type (correctly

Figure 3. Mean percentage of correct responses on correctly cued and miscued trials as a function of retention interval in Experiment 2.



Correctly Cued
Miscued
100
90
80
70
60
50
0
Percent Correct
0
1
5
Retention Interval (seconds)

vs incorrectly cued) and Delay (1 or 5 s). As in Experiment 1, there was a significant effect of Trial type, $F(1,5) = 13.90$, $p<.01$, and a significant Trial type x Delay interaction, $F(1,5) = 16.63$, $p<.01$. Matching accuracy on correctly cued trials was significantly higher than that on miscued trials at the short delay ($t(5) = 3.73$, $p<.01$). The difference in matching accuracy between correctly and incorrectly cued trials at the long delay was not significant ($t(5) = 1.8$, $p>.05$). No other main effects or interactions were significant.

Keypecking during retention interval cue presentation was recorded. Data was collapsed over blocks of sessions. Rate of responding was higher in the presence of the "short" cue (3.05 pecks/s) than in the presence of the "long" cue (0.91 pecks/s). A one way ANOVA revealed that this effect was reliable ($F(1,5) = 5.83$, $p<.05$.

Discussion

The results of the second Experiment are very similar to those of Experiment 1. Presentation of a "long" cue on short delay trials greatly reduced matching accuracy, in comparison to correctly cued trials. Presentation of a "short" cue on long delay trials did not result in significantly increased matching accuracy, relative to correctly cued trials. That this effect occurs when the cues are presented only during the retention interval suggests that the miscuing effect is not due to differential attention to the sample stimulus.

IV. Experiment 3

Based on the results of the previous two experiments, it is clear that cues signaling the length of an upcoming retention interval affect matching-to-sample accuracy. The presentation of a "long" cue on short delay trials results in a significant reduction in matching accuracy, relative to correctly cued trials. This effect occurs when the cues are presented in compound with the sample (Experiment 1) or when the cues are presented during the retention interval only (Experiment 2). Moreover, a comparison of Experiments 1 and 2 suggests that the magnitude of the miscuing effect is unaffected by whether the cues are or are not present during sample presentation. The present experiment involved a direct comparison of the miscuing effect produced by both types of cue presentation. Test sessions included compound cue/sample trials and post-sample cued trials. Both types of cued trials were compared with equal numbers of miscued trials.

Method

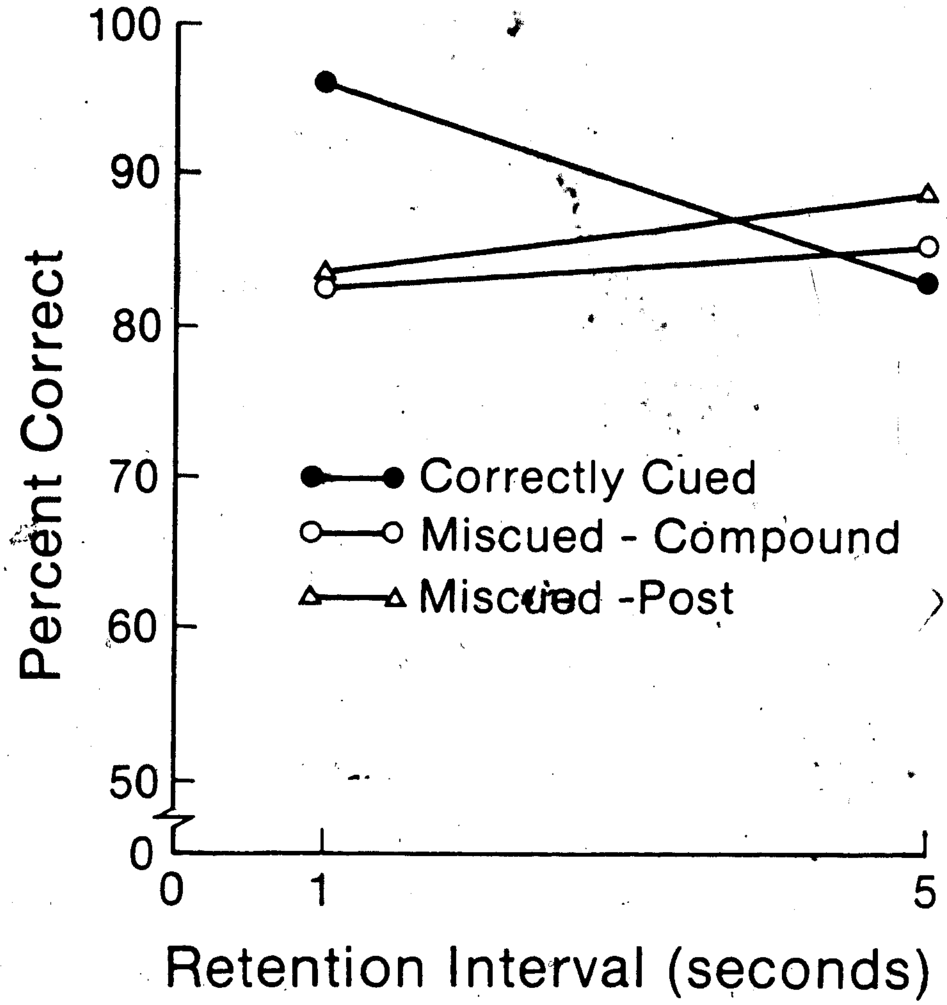
Subjects and Apparatus. The five Group B birds were used. The apparatus was the same as that used in the previous two experiments.

Procedure. The five Group B birds received 12 sessions of baseline training after Experiment 1 and prior to Experiment 3. Baseline sessions were identical with those described in Experiments 1 and 2. Experiment 2 test sessions consisted of 96 trials, 64 of which were were baseline. On baseline trials, the cue was presented in compound with the sample and continued into the retention interval for 1 s. Test trials consisted of 16 correctly cued trials, and 16 incorrectly cued trials. On half of the correctly cued trials, and half of the incorrectly cued trials, the cue was presented in compound with the sample ("Compound" trials). On the remaining half of both types of test trials, the cue was presented in the retention interval only, post-sample ("Post" trials). Two baseline sessions were run after every test session to insure that the cues did not lose their informative value due to the number of miscued probe trials presented during test sessions. Four test sessions were run.

Results

The mean percentage of correct responses on correctly and on the two types of incorrectly cued trials is shown in Figure 4. Performance on the two types of miscued trials was highly similar at each retention interval. A Procedure (compound and post) x Delay (1 and 5 s) ANOVA performed on the data from miscued trials revealed that matching accuracy was unaffected by the method of cuing, $F < 1.0$. One-tailed t tests revealed that accuracy at the short delay was significantly lower on both types of miscued trials than on correctly cued trials ($t(4) = 3.07$ and 2.80, both $ps < .05$, for

Figure 4. Mean percentage of correct responses on correctly cued, "Compound" miscued, and "Post" miscued trials as a function of retention interval in Experiment 3.


100
90
80
70
60
50
0
Percent Correct
Correctly Cued
Miscued - Compound
Miscued -Post
0
1
5
Retention Interval (seconds)

Compound and Post miscued trials, respectively). At the long delay, matching accuracy on miscued trials did not differ significantly from that on correctly cued trials ($t < 1.0$ in both cases).

Discussion

The present findings reveal that differential responding to the sample obtained when cues and samples are compounded contributes little, if at all, to the effectiveness of those cues in modulating matching accuracy. Interestingly, both Brown, Cook, Lamb and Riley (1984) and Santi and Roberts (1985) have concluded that the relationship between keypecking and matching accuracy is not a strong one. The results of the present experiment support this conclusion. Informative cues presented during the retention interval continued to affect matching accuracy, suggesting that sample keypecking is not an important determinant of the miscuing effect.

V. Experiment 4

The results of Experiments 2 and 3 rule out the possibility that informative cues modulate matching accuracy by influencing sample processing (i.e., strength of encoding). However, the observation in Experiments 1 and 2 that birds pecked during the retention interval at a higher rate on short-cued trials than on long-cued trials suggests that informative cues may modulate matching accuracy by influencing post-sample processing. Stonebraker and Rilling (1981) found a high correlation between matching accuracy and keypecking during the delay interval, and suggested that keypecking may be a colateral of cognitive rehearsal. According to this view, presentation of a short cue may provoke more intense and/or persistent post-sample processing. Presentation of a long cue may decrease or terminate post-sample processing.

The purpose of the present experiment was to test the notion that differential post-sample processing is the mechanism responsible for the cuing effect. If presentation of a "long" cue reduces the level of processing, then the rate of forgetting should be faster on long-cued trials than on short-cued trials, and the magnitude of the difference in matching accuracy on short- and long-cued trials should be greater at longer delay values. Experiment 4 involved the presentation of long and short cues at each of three retention interval durations (1, 3 and 8 s).

Method

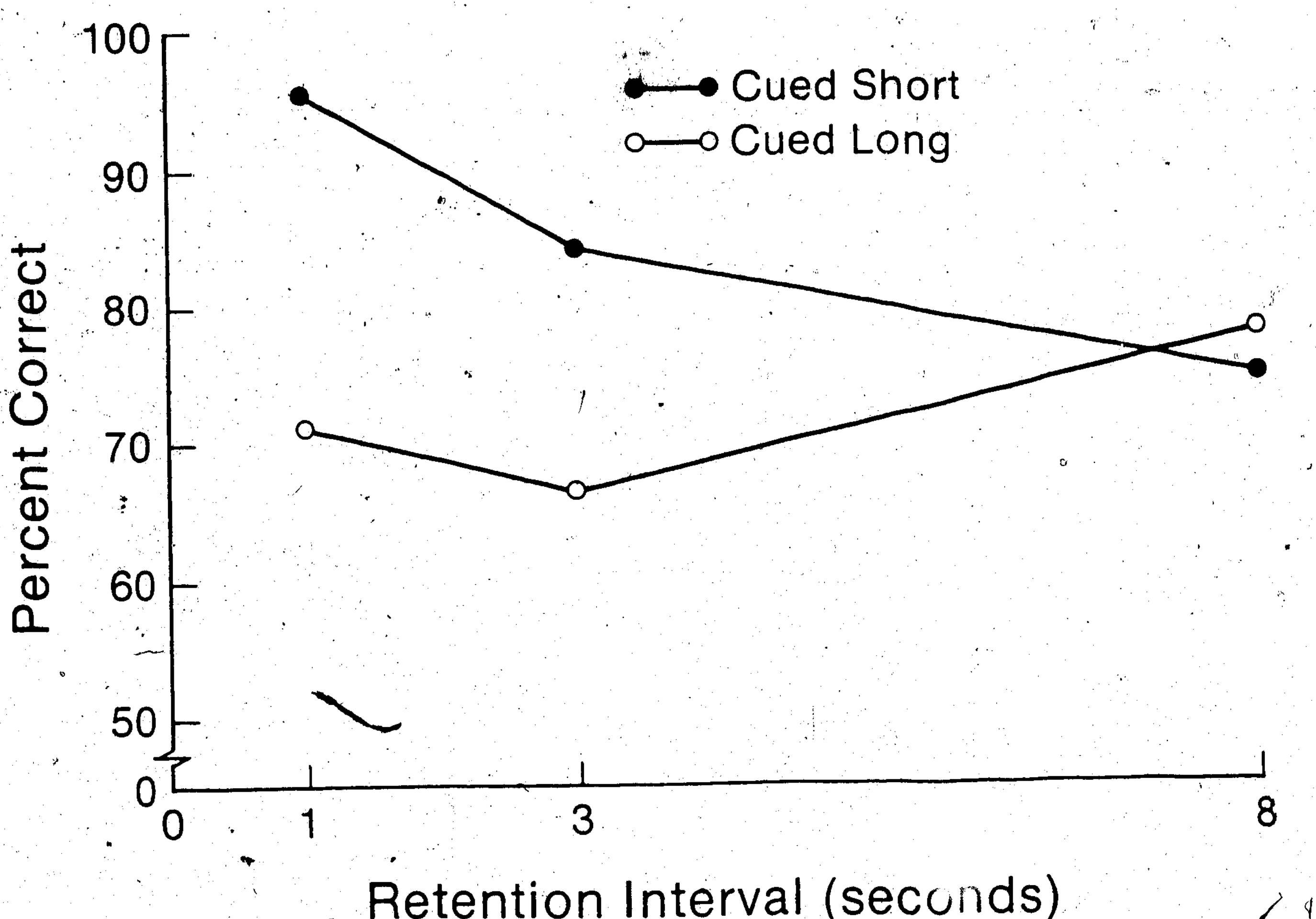
Subjects and Apparatus. Because a longer delay value (8 s) was used in this experiment, only birds that matched at a high level of accuracy at long delays served as subjects. Three Group A birds and all five of the Group B birds were used. The apparatus was the same as that employed in the previous experiments.

Procedure. As in Experiment 3, two baseline sessions identical with those of training (delays= 1 and 5 s) were run after every test session. Test sessions consisted of 80 trials. On all test trials, the informative cues were presented in compound with the sample stimulus and remained illuminated 1 s into the retention interval. Each test session consisted of 64 baseline trials (delays= 1 and 8 s). On the 12 of the test trials, the "short" cue was presented; the "long" cue was also presented on 12 trials. These 24 test trials were divided into 3 delay values: 1, 3 and 8 s. The "short" cue was presented four times at each delay value and the "long" cue was presented at each delay value four times. A total of four test sessions were run.

Results

The mean percentage of correct responses is shown in Figure 5. As is evident from the Figure, matching accuracy declined across the three delays on short-cued trials. This

Figure 5. Mean percentage of correct responses on short-cued and long-cued trials as a function of retention interval in Experiment 4.


Cued Short
Cued Long
100
90
80
70
60
50
0
Percent Correct
0
1
3
8
Retention Interval (seconds)

decline did not occur on long-cued trials. Further, matching accuracy was much lower on long-cued trials at the 1 and 3 s delays than on short-cued trials. At the longest delay (8 s), the level of matching accuracy converged on short- and long-cued trials.

An analysis of the data with Cue type (short or long) and Delay (1,3 or 8 s) as the factors revealed a significant effect of Cue type, $F(1,7) = 12.75$, $p<.01$, and Delay, $F(2,14) = 3.81$, $p<.05$. The Cue type x Delay interaction was also significant, $F(2,14) = 4.01$, $p<.05$. One-tailed t tests revealed that the level of performance at the shortest delay (1 s) was significantly lower on long-cued trials than on short-cued trials ($t(7) = 3.96$, $p<.05$). Accuracy on long-cued trials was lower than on short-cued trials at the 3 s delay as well, although this difference was somewhat less than at the 1 s delay ($t(7) = 2.19$, $p<.05$). The difference between short-and long-cued trials at the longest delay was not statistically significant ($t(7) = .44$, $p<.05$).

Discussion

The present findings clearly are not in accordance with the view that presentation of a "long" cue affects the processing of the sample stimulus memory. If the long cue reduces the amount of processing of the sample memory, and thus increases the rate of forgetting, the magnitude of the difference in matching accuracy on short-and long-cued trials should be greatest at long delays. The difference in matching accuracy should be least at short delays. This was clearly not the case in the present experiment. Thus, no support was obtained for the notion that presentation of the "long" cue reduces postsample processing or rehearsal.

The present experiment also revealed that matching accuracy at the 8 s delay was unaffected by cuing. Honig and Dodd (1986) have suggested that informative cues may generate anticipations of trial characteristics, such as the duration of the retention interval. These anticipations, like the memory of the sample stimulus, may be forgotten after long delays. Thus, the informative cues may not be effective at long delays. This may explain the convergence of matching accuracy on short and long-cued trials at the longest delay.

VI. Experiment 5

The results of the previous experiment suggested that cuing retention interval length may not affect the rehearsal or processing of information. To test this possibility further, the point of cue presentation within the retention interval was manipulated. The "long" cue was presented at either the beginning or the end of the retention interval on short delay trials. If the "long" cue terminates or reduces processing of the information contained in memory, the point of cue placement should be an important determinant of matching accuracy at test. Specifically, a "long" cue presented early in the retention interval should be maximally effective in reducing matching accuracy. As the interval between sample termination and cue presentation is lengthened, the cue should be progressively less effective.

Method

Subjects and Apparatus. The subjects were the same 8 birds that were employed in Experiment 4. The apparatus was the same as that used in all previous experiments.

Procedure. Two baseline sessions were run after every test session, and were identical with those of the previous experiments. Test sessions consisted of 80 trials, 64 of which were baseline. On 16 of the test trials, a "long" cue was presented during the short delay. On 8 of these miscued trials, the cue was presented during the first second of the retention interval. On the remaining 8 miscued trials, the cue was presented during the last second of the retention interval. Data from these miscued trials was compared with data from 8 correctly cued trials (cue presented during first s of retention interval). Two tests were run. In Test 1 (4 sessions) test trial delay was 2 s and in Test 2 (4 sessions) test trial delay was 3 s.

Results

The mean percentage of correct responses on test trials is shown in Table 1. Clearly, the point of cue placement within the retention interval did not differentially affect matching accuracy in either Test. The "long" cue reduced matching accuracy regardless of whether the cue was presented at the beginning or the end of the retention interval. An analysis of the data on long-cued trials revealed no significant effect of point of cue placement. There was no difference in the level of matching accuracy when the cue was presented at the beginning or the end of the retention interval. Matching accuracy on correctly cued short delay trials was significantly higher than accuracy on either the miscued-beginning or miscued-end trial types. One-way ANOVA's revealed that both effects were reliable (beginning: $F(1,7) = 5.35$, $p=.05$; end: $F(1,7) = 9.34$, $p<.05$).

Table 1

Accuracy on long cued trials in Experiment 5 as a function of point of cue interpolation.

	Long cue		
Delay	Beginning	End	Short cue
2 s	81.6	78.1	85.1
3 s	73.8	76.6	86.7
Mean	77.7	77.4	85.9

Note: Beginning = cue during first 1 s of delay. End = cue during final 1 s of delay.

Discussion

The results of this experiment provide further evidence against the hypothesis that the informative cues affect the processing of the sample stimulus memory. If the long cue depressed postsample processing, then accuracy should have been decreased more markedly by presenting that cue at the beginning, rather than the end, of the delay interval. The failure to obtain such an effect in the present experiment, taken in conjunction with the findings of Experiment 4, permit rejection of the rehearsal account of the cuing effect.

VII. General Discussion

Experiments 1, 2 and 3 of the present study have shown that the cuing effect reported by Wasserman et al. (1982) and Dodd and Honig (1981) is very robust. The first experiment constituted an extended replication of Wasserman et al.'s Experiment 2. The effect was demonstrated in the present Experiment 1 using a two-choice delayed matching-to-sample procedure, with two independent groups of birds. Signaling a "long" delay but presenting a short one significantly decreased matching accuracy relative to correctly cued trials.

Experiments 2 and 3 revealed that the effect is not due to differential attention to the sample stimulus. The cues continued to affect matching accuracy when presented only during the retention interval, the post-sample cuing procedure (Experiments 2 and 3). This effectively rules out the possibility that the informative cues control the amount of attention or encoding given to the sample. A within-subject comparison between cues presented in compound with the sample stimulus and cues presented during the delay was a further demonstration of the inadequacy of the differential attention explanation. Both types of cue presentation were of approximately equal effectiveness in producing the cuing effect (Experiment 3).

The cuing effect has also been demonstrated in humans.

Hinrichs and Grunke (1975) presented informative time-tags correlated with retention interval length for a paired-associate learning task. The cues increased performance at short delays, relative to uncued control items. Performance was not facilitated at long delays. They argued that subjects differentially allocated resources or rehearsal strategies on short-cued items.

However, the results of Experiments 4 and 5 in the present series suggest that, in pigeons, informative cues correlated with retention interval length do not affect the processing of the information contained in memory. Presentation of a "long" cue resulted in a uniform reduction in matching accuracy across a range of delay values, indicating that the "long" cue does not affect the rate of forgetting (Experiment 4). In Experiment 5 the point of "long" cue placement within a short retention interval was manipulated. Matching accuracy was decreased equally when the cue was presented at the beginning or the end of the interval. The results of the two experiments argue strongly against a processing or rehearsal interpretation of the cuing effect.

The performance decrement observed on long-cued trials may be due to differences in reinforcer value on short and long cued trials. Short delay trials offer proportionately more reinforcement per minute than do long delay trials.

Rachlin and Green (1972) made birds wait differing lengths of time for reinforcement of differing durations. They suggested that reinforcement rate is equal to reinforcement duration divided by the delay of reinforcement delivery. Extrapolating from that notion, Wasserman et al. (1982) suggested that reinforcement rate is equal to the probability of reinforcement divided by the delay of reinforcement delivery. They employed this revised formula in their Experiment 3 to equate reinforcement rate on short and long delay trials. The probability of reinforcement delivery after a correct match following a short delay was reduced to 0.25; the probability of reinforcement delivery after a correct match following a long delay remained at 1.0. Thus, pigeons received reinforcement four times more often following the long delay (8 s) than after the short delay (2 s). This manipulation, according to the revised formula, equated the different rates of reinforcement on the two types of trials. As in their previous experiment, a flatter retention function was observed with correlated cues, indicating that rate of reinforcement is not a primary determinant of the cuing effect.

However, the Rachlin and Green (1972) formula for calculating rate of reinforcement may not be applicable in the case of delayed matching-to-sample. Contemporary notions of matching suggest that pigeons actively process sample information during the retention interval (e.g. Grant, 1981; Grant, 1984; Maki, 1981). In a DMTS procedure, birds are not simply required to wait a certain period of time before reinforcement delivery (as in the Rachlin & Green study) but may process sample information during the delay interval. Delayed reinforcers in this procedure may be more heavily discounted, and the Rachlin and Green formula may not actually equate reinforcer value on short and long delay trials.

The cuing effect, then, may occur because of differences in overall reinforcer value on short and long delay trials. The informative cues may generate anticipations of reinforcer value and these anticipations may have controlled matching accuracy by affecting motivation to respond correctly at the time of test. Presentation of a "long" cue correlated with low reinforcer value may have reduced motivation to respond accurately. Research directed at controlling the differences in reinforcer value on short and long delay trials is necessary to determine the mechanism of the cuing effect.

The results of the series of experiments reported here suggest that informative cues signaling the length of an upcoming delay interval influence neither sample encoding nor post-sample processing. It appears that the cues modulate accuracy by influencing test responding independently of memory. Previous research on pigeon short-term memory has also shown that errors in matching-to-sample tasks do not necessarily reflect memory loss. Roberts and Grant (1978) proposed that an autoshaped or classically conditioned "elicitation" process operates in delayed matching tasks. They suggested that this elicitation process results in a tendency to peck at a comparison stimulus without comparing the information contained on the pecking key to that contained in memory. According to Roberts and Grant, some proportion of the errors that occur in a delayed matching task are due to this non-memorial elicitation process.

Wilkie and Spetch (1981) have also suggested that delayed matching-to-sample errors are not always due to forgetting. They studied pigeons' matching behavior in a modified DMTS task. A single response to one of the comparison stimuli resulted in the termination of the alternative comparison. Twenty-nine additional responses to the illuminated comparison were required before reinforcement or nonreinforcement occurred. They found that the birds took more time to complete the peck requirement after an incorrect match than after a correct match. They suggested that the birds were making "impulsive" errors, and the increased completion time after errors was due to the anticipation of nonreward. Wilkie and Spetch concluded that errors in a delayed matching task may arise in the absence of forgetting.

The present results may have important implications for short-term memory research using delayed matching techniques. It is possible that the passage of time in a typical DMTS task functions as an implicit long delay cue. As suggested by the present results, long delay values may reduce the motivation to respond correctly at the time of test. The reduced matching accuracy typically observed at long delay values may be due, in part, to this non-memorial motivational factor. If this is the case, delayed matching tasks may overestimate the rate of forgetting.

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