Memory in the pigeon: Retroactive inhibition in a delayed matching task*

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Six pigeons were trained on a wavelength matching-to-sample task with a 5-sec delay between the offset of the sample and onset of the comparison stimuli. When a novel wavelength or novel shape was interpolated between the sample and comparison stimuli, both disrupted matching performance, and the novel wavelength was more disruptive than the novel shape. The results suggest that interpolated stimulus presentation disrupts the memory trace for the sample stimulus.

The delayed matching-to-sample task is well suited for the study of short-term memory in animals. The task involves presentation of a sample stimulus, followed by a delay, followed by presentation of two or more comparison stimuli. Responses to the comparison stimulus, which is the same as (matches) the sample stimulus, are reinforced. The comparison stimulus presentation is essentially a recognition test for a previously presented stimulus. With this task, one can study not only the effects of delay-interval manipulation but also the effects of presenting other stimuli prior to sample-stimulus presentation (proactive inhibition) and of interpolating other stimuli during the delay interval (retroactive inhibition). Traditionally animal studies employing retroactive inhibition and proactive inhibition paradigms have involved the learning of one task (i.e., turning left in a T-maze), followed by the learning of a second task (i.e., turning right in a T-maze), followed by an immediate or delayed retention test of either the first task (RI) or the second task (PI) (see, for example, Crowder, 1967). The problem with comparing these retention losses in animals with those found in similar human studies is that human Ss are given explicit instructions at the time of recall, whereas animals are not. While some effort has been made to provide "instructions" to animals at the time of the test by the use of task-specific contextual cues (Chizar & Spear, 1969; Zentall, 1970), the delayed matching-to-sample task is a better means of assuring that the task requirements, at the time of test, have been learned. The fact that an animal can perform at a high level of accuracy on control trials involving only sample and comparison stimuli presentation indicates that the task

"instructions" have been learned, and any drop in performance produced by the introduction of other stimuli before or after the sample stimulus can be attributed to sample-stimulus retention loss.

As part of a larger study, Jarvik, Goldfarb, & Carley (1969) studied RI in monkeys using the delayed matching-to-sample task and varied both the nature of the interpolated stimulus (same as the sample, same as the incorrect comparison, novel) and its temporal location during the delay. They found that (1) presentation of the sample stimulus during the delay slightly facilitated matching performance, especially when presented toward the end of the interval, (2) presentation of the incorrect comparison stimulus during the delay produced a large drop in performance wherever it was presented in the delay interval, and (3) presentation of a novel stimulus produced a slight drop in performance, but only when presented midway during the delay. Results of the interpolation of stimuli from the matching task during the delay are difficult to interpret, in light of the problem of task instructions.

Presentation of the sample stimulus during the delay is a special case of the RI paradigm in which further exposure to the sample stimulus is provided, effectively reducing the delay so that no RI would be expected. Presentation of the incorrect comparison stimulus during the delay is also a special case, for the sample stimulus is arbitrarily defined by the E as the one that came first. Any tendency to respond to "the stimulus last seen" may produce a drop in performance not necessarily attributable to a loss of retention. Presentation of a *novel* stimulus during the delay is a better test of retention loss, independent of task instructions, for it possesses none of the ambiguity involved with presentation of the incorrect stimulus and does not shorten the effective sample-comparison delay interval, as is the case with presentation of the sample stimulus.

The purpose of the present experiment was to study with pigeons the effects of the presentation of stimuli (different from the stimuli used in the matching task) during the delay interval. Does presentation of novel stimuli during the delay disrupt matching performance? Does the amount of disruption depend upon the nature of the interpolated stimulus?

METHOD

Subjects

Six female white Carneaux pigeons, approximately 1 year old, were maintained at 80% of their free-feeding weights. All birds had had extensive prior training on a wavelength (red-green) delayed matching-to-sample task at various delays up to 8 sec.
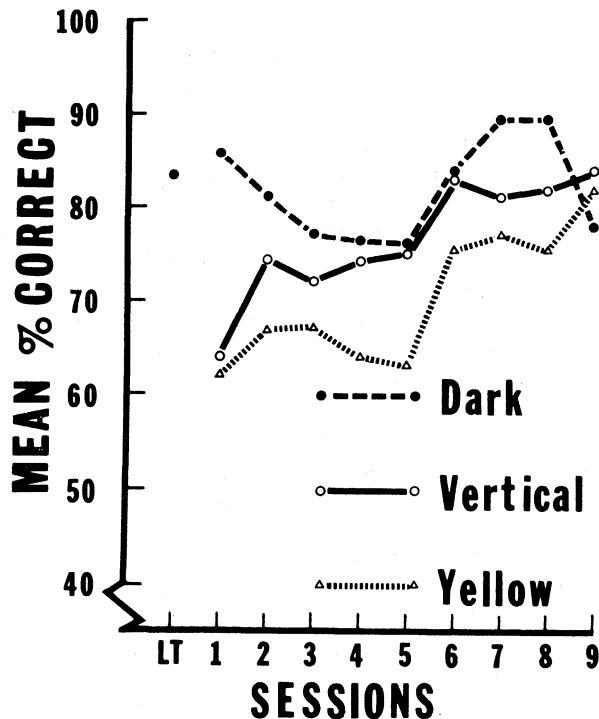
Fig. 1. Mean performance on a 5.0-sec delayed matching-to-sample task as a function of novel stimulus presentation during the delay on random trials. Session LT is the last training session prior to the introduction of novel stimuli during the delay.

Apparatus

The experimental box was a standard three response-key Lehigh Valley Electronics pigeon test chamber, with in-line readout projects (IEE Series 10) behind each key. The stimuli used were: a white vertical line 3.5 mm wide on a black background, a green field (Kodak Wratten Filter 60), a red field (Kodak Wratten Filter 26), and a yellow field (Kodak Wratten Filter 12). A dim houselight, located 7 cm above the center key, was on throughout the session, except during the intertrial interval (ITI). Reinforcement consisted of 3 sec access to mixed grain (Purina pigeon grain). External sound masking was provided by white noise and a blower fan.

Procedure

Baseline Training

All birds were given training with a red-green delayed matching-to-sample task. At the start of a trial, the center key was illuminated (red or green). Five responses to the center key terminated the stimulus on the center key and initiated a 5-sec interstimulus delay (ISD). Completion of the ISD lighted the two side keys (one red, one green). With the two side keys illuminated, a side key response turned the keys off and initiated a 5-sec ITI. A response to the side key of the same color as the previously presented center key produced reinforcement. A response to the other side key produced only an ITI. With the center key alone illuminated, response to the darkened side key had no effect. With the two side keys illuminated, response to the darkened center key had no effect.

Seven sessions of 96 trials each were run daily, with center key color and correct side key (left or right) randomly assigned throughout the session with the constraint that any particular position or color could not be correct for more than three consecutive trials. Two different within-session trial orders were used and alternated haphazardly from day to day.

Test

Following baseline training, nine test sessions were run in which the center key was illuminated *during* the ISD on two-thirds of the trials. On half of these illuminated trials, a yellow field was presented throughout the ISD; on the other half, a vertical white line was presented throughout the ISD. On the remaining trials, the stimulus key was dark during the ISD. The sequence of trials was semirandomly determined and counterbalanced over matching trials. In all other respects, trials were the same as during baseline training. In addition to the number of correct responses for each of the ISD stimuli, cumulative ISD responses were recorded.

RESULTS AND DISCUSSION
Baseline Training Data

Performance was quite stable over the seven training sessions. Mean percent correct over the first three sessions was 80.8%, as compared with 79.6% over the last three sessions. Performance over days did not vary significantly, $F < 1$.

Test Data

Data from the test sessions are presented in Fig. 1.

A two-way analysis of variance performed on the test data indicated a significant treatment effect $[F(2,135) = 13.45, p < .01]$ and a significant sessions effect $[F(8,135) = 3.61, p < .01]$ but a nonsignificant Treatment by Sessions interaction. Planned comparisons indicated that performance on interpolated stimulus trials was significantly below performance on control (dark key) trials $[F(1,135) = 14.29, p < .01]$, and performance on interpolated yellow field trials was significantly poorer than vertical line trials $[F(1,90) = 7.08, p < .01]$. The difference between performance on dark key trials and yellow field trials over sessions was also significant $[F(26,135) = 1.85, p < .05]$, as determined by post hoc analysis (Scheffé, 1959). Mean performance over sessions was 81.8% for dark key trials, 76.7% for vertical line trials, and 70.4% for yellow field trials.

While the Treatment by Sessions interaction was not significant, such an effect may be obscured by the daily fluctuations in overall performance (see mean performance on dark key trials over sessions in Fig. 1). Since each bird served in each treatment and each session, a more sensitive measure of the treatment effect as a function of test session is a disruption score for each bird, on each day, for each of the two interpolated stimuli (percent correct on the dark key trials minus percent correct on the yellow or vertical line trials). An analysis of variance performed on the disruption scores indicated a significant treatment effect $[F(1,90) = 5.69, p < .05]$, a significant sessions effect $[F(1,90) = 2.99, p < .05]$, and a significant linear trend over sessions $[F(1,90) = 12.60, p < .01]$. The significant linear trend indicates a progressive reduction in disruption of matching performance by interpolated stimuli, as a function of test sessions.

One might conclude from the above results that disruption of performance on a delayed matching task is

a function of the "similarity" between interpolated stimuli and the stimuli to be matched. But one could argue that it is not the similarity of the interpolated stimuli to the comparison stimuli, but the saliency of the interpolated stimuli, which produces differential disruption. A yellow field may be inherently more salient than a white vertical line on a black background, regardless of the stimuli to be matched. The more salient the interpolated stimulus, the more distracting it may be. Whether it is the similarity of the interpolated stimuli to the stimuli to be matched or the saliency of the interpolated stimuli which determines the amount of disruption, the present study indicates that stimulus events occurring during the ISD can have an important effect on retention of the sample stimulus, even when the interpolated stimuli are quite different from either of the comparison stimuli presented at the time of test. The present results with pigeons are comparable to the Jarvik, Goldfarb, & Carley (1969) findings with monkeys, in which novel stimulus presentation in the middle of the ISD produced significant disruption of a delayed matching task.

Disruption of delayed matching performance by novel stimulus presentation during the ISD can most easily be explained by a "novelty" or general distraction hypothesis (i.e., a kind of external inhibition). If this were the case, however, one would expect the disruption to dissipate quite rapidly as habituation occurred to the novel stimulus. That the disruption persists over hundreds of stimulus presentations, at least for the novel yellow stimulus, suggests the possibility that more than distraction occurred. The persistence of the disruption suggests that the interpolated stimulus interfered with or competed with the sample stimulus memory trace. Competition between the sample and interpolated stimuli at the time of test is unlikely, however, given the use of a recognition test in which the interpolated stimulus is never presented. Thus, from the above data, it appears as if interpolated stimulus presentation produces an actual memory loss for the sample stimulus. That is, presentation of a stimulus during the ISD disrupts the memory trace for the sample stimulus.

Behavior During the ISD

Individual differences in disruption may be affected by the birds' behavior during the ISD. Since the onset of the side keys acts as a discriminative stimulus signaling the availability of reinforcement, the fixed duration of the ISD is likely to produce superstitious behavior (i.e., pecking at the dimly lit houselight). Behavior which removes the bird from the presence of the center key during the ISD should reduce the disruption produced by novel stimulus presentation during the interval. On early test sessions, the birds are likely to orient toward the novel stimuli. Since this orienting behavior is likely to be correlated with a drop in performance, due to the interfering effects of the novel stimulus, one might expect the birds to shift to other activity during the ISD. It may be that the birds which showed minimal disruption of the matching task upon presentation of novel stimuli were those which had developed well established superstitious behaviors during training. While a great deal of superstitious houselight-pecking behavior was observed during the course of training, no systematic measures were taken.

If behavior during the ISD is related to the disruption produced by interpolated stimuli, then one might expect a positive correlation between the amount of disruption and the number of center key responses during the ISD. The data indicate, however, that the number of center key responses is not a good predictor of disruption (as determined by rank-order correlation), either on the first test session (R = .43, p > .10) or pooled over sessions (R = −.14). On the other hand, it is quite clear that as performance is improving over test days the number of ISD responses is declining [F(8,45) = 3.57, p < .01] with a significant linear trend [F(1,45) = 23.93, p < .01].

It may be that ISD responses are an insensitive predictor of performance, because birds need not peck at the ISD stimulus for it to disrupt matching performance. Merely observing the interpolated stimulus may be disruptive. Since orienting toward the ISD is necessary to enable the interpolated stimulus to disrupt the matching task, one might increase the observed disruption by transforming the novel stimulus into an S+ (i.e., reinforcing responses to the stimulus) in another context. The results of such an experiment might help clarify the function of the interpolated stimulus.

The present experimental results also have implications for a finding by D'Amato & O'Neill (1971) that delayed matching-to-sample performance in monkeys is poorer when the houselight is left on (or turned on) during the ISD than when no light is present during the ISD. If the houselight functions as an interpolated stimulus, the resulting disruption in performance can be attributed to RI. The observation from the present experiment that birds often peck at the houselight during the ISD provides support for the position that the houselight can function as a stimulus. If this interpretation is correct, one should be able to improve baseline performance, and perhaps increase the interpolated stimulus disruption found in the present study, by turning the houselight off during the ISD.

REFERENCES

Chizar, D. A., & Spear, N. E. Proactive interference in a T-maze brightness-discrimination task. Psychonomic Science, 1968, 11, 107-108.

Crowder, R. G. Proactive and retroactive inhibition in the retention of a T-maze habit in rats. Journal of Experimental Psychology, 1967, 74, 167-171.

D'Amato, M. R., & O'Neill, W. Effect of delay-interval illumination on matching behavior in the capuchin monkey. Journal of the Experimental Analysis of Behavior, 1971, 15, 327-333.

Jarvik, M. E., Goldfarb, T. L., & Carley, J. L. Influence of interference on delayed matching in monkeys. Journal of Experimental Psychology, 1969, 81, 1-6.

Scheffé, H. The analysis of variance. New York: Wiley, 1959.

Zentall, T. R. Effects of context change on forgetting in rats. Journal of Experimental Psychology, 1970, 86, 440-448.