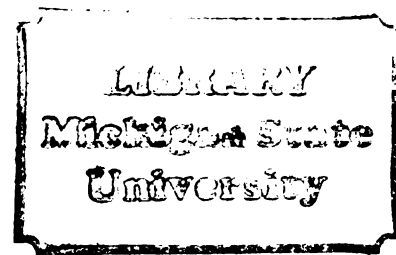




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ASSOCIATIVELY-GENERATED RETRIEVAL
IN PIGEON SHORT-TERM MEMORY

By

Donald F. Kendrick

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

ASSOCIATIVELY-GENERATED RETRIEVAL IN PIGEON SHORT-TERM MEMORY

By

Donald F. Kendrick

Memory of one stimulus may be retrieved from long-term memory by the presentation of another stimulus with which it is associated. This reactivation process has been invoked to explain sensory preconditioning and second-order conditioning phenomena. In operant conditioning, retrieval hypotheses have also been advanced to explain some recent data in delayed matching-to-sample. The present experiments investigated the hypothesis of associatively-generated retrieval in delayed matching-to-sample. Pigeons were trained on serial conditioning to establish color-line associations, were next trained on color matching, and finally were trained on symbolic matching. The combined influence of serial conditioning and color matching was predicted to produce facilitated acquisition of symbolic matching in one group (Group C) and inhibited acquisition in a second group (Group I), relative to three control groups, one that was not trained in serial conditioning (Group N), one that received the serial conditioning stimuli unpaired (Group U) and one

that was not trained in color matching (Group CN). Acquisition of symbolic matching was found to be inhibited in Group I, as predicted, but not significantly facilitated in Group C, although Group C did perform at higher levels than the other groups. The results indicate that retrieval of stimulus information from long-term memory is a function of learned associations among stimuli. This finding supports the notion that retrieval processes may be operative in pigeon short-term memory and thereby mediate delayed matching performance.

To my parents, and their parents.

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I am most grateful to Dr. Mark Rilling for encouragement, guidance, and the generous donation of his time and goodwill toward the completion of the dissertation and my graduate training. I am also indebted to the members of my guidance committee, Dr. Denny, Dr. Carr, and Dr. King, for the enlightening and enjoyable conversations we shared.

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INTRODUCTION

Recently, a great deal of theoretical and experimental effort has been expended on studies of short-term memory in rats (Grant, 1980; Lieberman, McIntosh, & Thomas, 1979; Olton, 1977; 1978; Roberts, 1979; Roberts & Smythe, 1979), pigeons (Grant 1981; Kendrick, Rilling, & Stonebraker, 1981; Maki & Hegvik, 1980; Roberts & Grant, 1978; Tranberg & Rilling, 1980; Weisman, Wasserman, Dodd, & Larew, 1980; Wright & Sands, 1981; Zentall, Edwards, Moore & Hogan, 1981), and monkeys (D'Amato, 1973; Medin, Reynolds, & Parkinson, 1980; Mishkin & Delacour, 1975; Reynolds & Medin, 1981). One important area in this research is the investigation of rehearsal and retrieval of stimulus information in animal short-term memory.

In pigeons, short-term memory is most often studied using the delayed matching-to-sample paradigm. In one version of delayed matching, four trials of two sequentially presented stimuli are arranged such that responding to the second stimulus of the pair is

reinforced only if it physically matches the first stimulus. This is the go/no-go procedure (Wasserman, 1976), and is of the form, red-red, red-green, green-green, and green-red. This is a conditional discrimination requiring the pigeon to remember the first stimulus in order to respond appropriately during the second. Learning is indicated by low rates of responding during the second stimulus on the nonmatching trials, red-green and green-red, relative to the high rates of responding on the matching trials, red-red and green-green. Short-term memory is investigated when a delay is imposed between the first and the second stimulus.

Current theoretical formulations concerning animals' ability to remember the first stimulus invoke a rehearsal process, a retrieval process, or both. The concept of rehearsal as a process of maintenance of stimulus representations in short-term memory stems from several sources. For example, Wagner (1976; 1981) has long proposed that representations of conditioned stimuli (CSs) and unconditioned stimuli (USs) occupy a limited capacity short-term memory buffer and that the co-occurrence of their representations in this buffer results in the

formation of the CS-US association. Also, Shimp (1976) proposed that the behavioral unit that enters response-reinforcer associations may be defined as the sequence of behavior held in short-term memory at the time of reinforcement. In addition, Maki (1979; Maki & Hegvik, 1980) and others (e.g., Grant, 1981; Stonebraker, Rilling, & Kendrick, 1981) have argued that maintenance (i.e., rehearsal) of stimulus representations in short-term memory is a process that can come under external stimulus control. The concepts of rehearsal and retrieval are not mutually exclusive, but in general, rehearsal has been the focus of recent empirical work in pigeon delayed matching (Urcuioli & Honig, 1980; Maki, Olsen, & Rego, 1981; Roitblatt, 1980; Zentall, Hogan, Howard, & Moore, 1978).

Other theoretical notions of short-term memory and delayed matching invoke a retrieval process (Grant 1980; Rilling, Kendrick, & Stonebraker, in press; Spear, 1981; Wagner, 1980). According to a retrieval concept, the test stimuli effect a scanning of recent memory for the representation of the previously-presented sample stimulus, which when located is reactivated in short-term memory (D'Amato & Worsham, 1974; Kendrick, Rilling, &

Stonebraker, 1981). The active memory of the sample is then compared against the physically present test stimulus to generate a response (see Wright & Sands, 1981, for a model of this response decision).

Recently, Wagner (1979) has proposed two basic types of retrieval, "self-generated retrieval", in which a representation of a physically present stimulus is activated in short-term memory, and "associatively-generated retrieval", in which one stimulus retrieves a representation of another stimulus with which it is associated. This notion has been investigated primarily in the context of classical conditioning in which a CS is said to retrieve the US representation (Holland & Rescorla, 1975; Konorski, 1967; Terry & Wagner, 1975; Wagner, 1978). However, recent studies have suggested that one CS may effect retrieval of the representation of another CS (e.g., Holland, 1981; Rescorla, 1980).

In the operant conditioning literature, retrieval has also been invoked to explain delayed matching data. For example, Kendrick, Rilling, and Stonebraker (1981) proposed that directed forgetting in pigeons was partially attributable to failure to retrieve memory of the sample

stimulus in delayed matching. Similarly, Grant (1980) proposed that retrieval of inactive memories may account for proactive interference in delayed alternation in rats.

Recently, Medin, Reynolds, and Parkinson (1980) suggested that stimuli interpolated into the delays of delayed matching in monkeys may effect retrieval of previously presented stimuli with which the interpolated stimulus is physically similar. Although retrieval is gaining acceptance as a theoretical possibility in animal short-term memory, little work has attempted to directly determine whether associatively-generated retrieval of past memories can influence current delayed matching performance.

The purpose of the present work is to demonstrate that associatively-generated retrieval of stimulus representations can influence acquisition of delayed matching-to-sample in pigeons. Such a demonstration indicates that retrieval processes involving learned associations play an important role in animal short-term memory as investigated in the delayed matching paradigm.

The general rationale was to first establish associations between color stimuli and line stimuli such that one color or line would retrieve a memory of its

associated line or color by using a serial conditioning procedure (Wasserman, Carr, & Deich, 1978) in which the two events were paired with food. Next, a delayed matching training task was established in which color stimuli served as samples and test stimuli. Finally, a symbolic matching transfer task was employed with line sample stimuli and color comparison stimuli. The lines and colors were those used in the first two phases. Given associatively-generated retrieval, the lines and colors of the symbolic matching task were predicted to retrieve memories of their associated lines and colors, thereby influencing the course of acquisition of symbolic matching.

Specifically, the experiment was conducted in three phases as follows. In Phase I, a serial conditioning procedure (Wasserman, Carr, & Deich, 1978) was used; pecks during successively presented pairs of keylight stimuli (red-vertical and green-horizontal) were reinforced in order to establish associations between the colors and lines. In Phase II, the birds were trained on true color matching in which pecks during matching sequences of red-red and green-green were reinforced with food and pecks during the nonmatching sequences, red-green and

green-red, were not. In Phase III, the pigeons were trained on symbolic matching in which the vertical and horizontal lines replaced the red and green sample stimuli of Phase II, thus generating the four symbolic delayed matching trials: vertical-red, horizontal-green, vertical-green, and horizontal-red.

The rationale is that by virtue of previous association with red, the vertical line effects retrieval of a representation of red and by virtue of association with green, the horizontal line effects retrieval of a representation of green. Thus Phase III training on the symbolic matching task is "associatively-similar" to Phase II training on the color matching task. That is, to consider only one set of stimuli, having learned that red followed by red is a positive combination, and given that a vertical line retrieves a memory of red, then the vertical line-red trial of symbolic matching is "associatively-similar" to the red-red trial of color matching. It is also possible that the red test stimulus may effect retrieval of the memory of the vertical line; indeed, both stimuli may reactivate memory of the other. In either case, learning symbolic matching is predicted to be modulated by the combined influence of

associatively-generated retrieval and by the associations of the color matching sequences with food and no food.

To demonstrate associatively-generated retrieval two experimental groups and three control groups were formed on the basis of trial outcomes (see Table 1). For the congruent group (C), the outcomes of the symbolic matching trials were congruent with the outcomes of the color matching trials. This congruency assumes an "associative equivalency" of vertical and red, and of horizontal and green, by virtue of the Phase I serial conditioning. That is, vertical-red and horizontal-green were positive trials in Phase III symbolic matching just as red-red and green-green were positive trials in Phase II color matching. The vertical-green and horizontal-red trials were negative trials; congruent with the negative trials of color matching, red-green and green-red. Therefore, when the line effect retrieval of their respective color representations, trial outcomes are consistent with previous learning and facilitation of acquisition of symbolic matching is predicted.

Table 1

Sequence of training procedures for all five groups.

Group	Phase I	Phase II	Phase III
GpC	GH+ RV+	GG+ RR+ RG- GR-	HG+ VR+ VG- HR-
GpI	GH+ RV+	GG+ RR+ RG- GR-	HG- VR- VG+ HR+
GpU	G+ R+ H+ V+	GG+ RR+ RG- GR-	HG+ VR+ VG- HR-
GpN	x x x x	GG+ RR+ RG- GR-	HG+ VR+ VG- HR-
GpCN	GH+ RV+	x x x x	HG+ VR+ VG- HR-

G = Green, R = Red, H = Horizontal line, V = Vertical line, + = Food Reinforcement, - = No Food Reinforcement, x = No training.

For the incongruent group (I), the trial outcomes of symbolic matching were reversed from those of color matching. Red-red and green-green were positive in Phase II so vertical-red and horizontal-green were positive in Phase III. Now when the lines effect retrieval of their associated color representations, trial outcomes are inconsistent with previous learning, and inhibition of acquisition of symbolic matching is predicted.

Three control groups were also employed. It is possible that experience with the colors and lines in Phase I serial conditioning may facilitate or inhibit later learning involving those colors and lines independently of the unique pairings. One group (U) was given Phase I training with the colors and line Unpaired. These birds were then treated the same as Group C in all other Phases. Since no association existed between colors and lines, these birds were predicted to acquire the Phase III symbolic matching task somewhere between the predicted facilitated acquisition of Group C and the predicted inhibited acquisition of Group I.

The second control group (N) was treated the same as Group C, except that serial conditioning of Phase I was

eliminated. This group received No serial conditioning of colors and lines. With no color-line associations, and no unpaired color and line experience, this group was predicted to acquire the symbolic matching task similarly to Group U, assuming that experience with colors and lines does not influence acquisition of the symbolic matching task.

The third control group (CN) was also treated the same as Group C, except that Phase II, color matching, was eliminated. Without color matching experience, associatively-generated retrieval should not facilitate or inhibit acquisition of symbolic matching. Moreover, color matching experience may facilitate or inhibit acquisition of symbolic matching independently of the color-line associations of Phase I. This group thus controls for the influence of color matching on symbolic matching. It is predicted that this group will not suffer inhibition or facilitation of symbolic matching.

Method

Subjects

Thirty naive adult White Carneaux pigeons, six per group, served. They were individually housed and maintained under constant illumination and temperature. The birds were reduced to and maintained at 80% ad lib $\pm$ 20 g.

Water and grit were available ad lib. A mixed grain was the daily ration, fed as required to maintain criterion weight, and also served as the food reinforcement during the experiment.

Apparatus

Electro-mechanical programming equipment controlled contingencies and recorded responses. Two three-key Lehigh Valley Electronics operant chambers with only the center response key operative were used. An IEE stimulus projector transilluminated the center response key with red (606nm), and green (555nm), and projected white vertical and horizontal lines white lines, 2.5 cm in length, on a black surround.

Procedure

There were three phases to the experiment. First was serial conditioning; second was true successive delayed matching to colors and a brief period of retraining the serial conditioning of the first phase; third was symbolic successive delayed matching. In all phases the number of responses during trial events was the dependent variable. Reinforcement was always 2.5 sec access to mixed grain. Sixty-four trials were conducted daily, five to six days per week. Initially, the pigeons were habituated to the operant chamber for one hr the first day. No keylight stimuli nor food were presented. On the second day, the birds were magazine trained with a constant 40 sec inter-food interval for 30 trials. A second session of magazine training was conducted when necessary. Following magazine training, 64 daily autoshaping trials were conducted for one or two days as required to establish reliable key pecking during the stimuli. The stimuli were red and green keylights. Phase I, serial conditioning, followed autoshaping.

Phase I. Serial Conditioning. Three groups, Group C, Group I, and Group CN, were trained with the green stimulus followed by the horizontal line and the red stimulus followed by the vertical line. The color stimuli

appeared for 10 sec after which a single peck terminated the color and initiated presentation of the appropriate line stimulus. After 10 sec of the line stimulus, a single peck initiated reinforcement. For the unpaired control group, Group U, the four stimuli were presented unpaired, each for 10 sec, and each followed by food contingent upon a single peck after the 10 sec had timed out. For Group N, no serial conditioning occurred. After autoshaping, Group N began Phase II, color matching. For all groups in this phase, the intertrial interval (ITI) was 30 sec and the 64 trials were pseudorandomly arranged such that not more than three of the same trial type occurred consecutively. This phase continued for 15 sessions.

Phase II. Color Matching. Four types of delayed matching trials were pseudorandomly arranged such that no more than three occurred consecutively. The four types were: Green-Green, Red-Red, Green-Red, and Red-Green. The stimuli were presented on the center response key separated by a delay interval of one sec. Reinforcement followed the Green-Green and Red-Red trials only. The first stimulus, the sample, was presented for a minimum of 10 sec and was terminated by a single peck after the 10 sec had timed out. Following the one sec delay, during which no stimuli were presented, the second stimulus, the

test stimulus, was presented for a minimum of six sec. If the test stimulus matched the sample stimulus, a single peck after the six sec had timed out produced reinforcement. If the two stimuli did not match, the test stimulus automatically terminated after the six sec without reinforcement. The trials were separated by a 30 sec ITI. Twenty daily sessions were required in this phase.

One group, Group CN, was not trained on color matching. Each bird of this group was held in the home cage for the equivalent time of twenty daily sessions.

At the end of this phase, and before continuing to the next phase, all birds were retrained on the serial conditioning task of Phase I for three sessions. The procedure for all groups was identical to that described in Phase I above.

Phase III. Symbolic Matching. This phase was the same as Phase II except as follows. Four types of trials were employed on this task: Horizontal-Green, Vertical-Red, Horizontal-Red, and Vertical-Green. For Group C, Group U, Group N, and Group CN reinforcement followed the color test stimuli on the Horizontal-Green and Vertical-Red trials. For Group I, reinforcement followed the test stimuli on the Horizontal-Red and Vertical-Green trials. Forty sessions were required during this phase. The dependent variable of interest is the learning performance

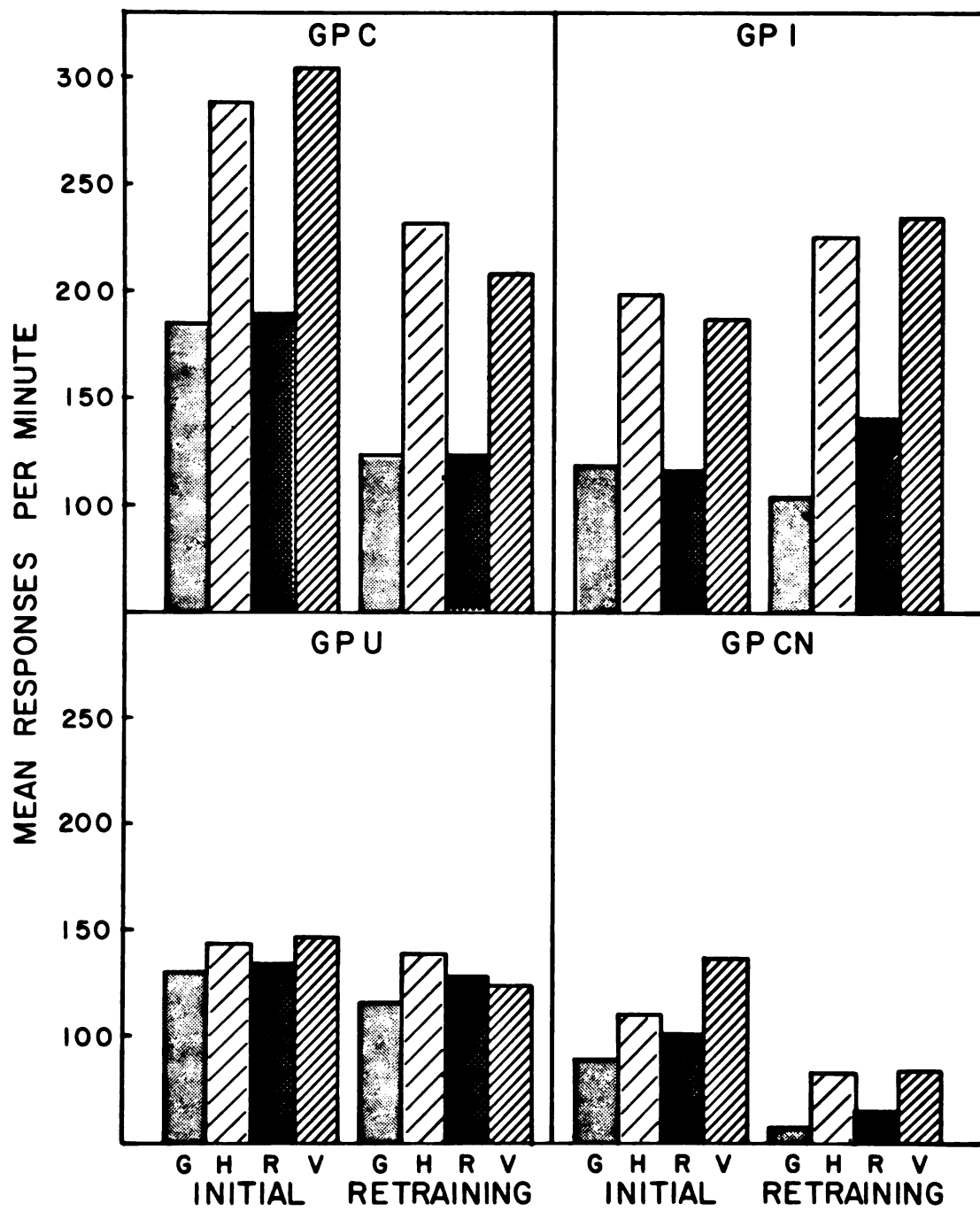
of the groups during this phase. Learning curves were plotted as a discrimination ratio defined as: the number of responses per minute during matching test stimuli divided by the sum of the number of responses per minute during the matching and the nonmatching test stimuli, all multiplied by 100. This ratio was calculated for each session, then a mean ratio was obtained for blocks of five sessions. These ratios were subjected to a split-plot factorial analysis of variance (Kirk, 1968).

Results

Serial Conditioning

Figure 1 shows the mean response rates of the four groups during the last five sessions of serial conditioning, left panels, and the three sessions of retraining, right panels. It is apparent from Figure 1 that Group CN and Group U responded at a lower mean rate than the other groups. The lower mean rate exhibited by Group U may be attributed to the individual presentations (Unpaired) of the keylight stimuli. The lower mean rate exhibited by Group CN can be explained by individual

Figure 1. Mean responses per minute during the four stimuli of serial conditioning over the last five sessions of Phase I training (initial) and the three sessions of retraining. Green (G), a Horizontal line (H), Red (R), and a Vertical line (V) were the stimuli.



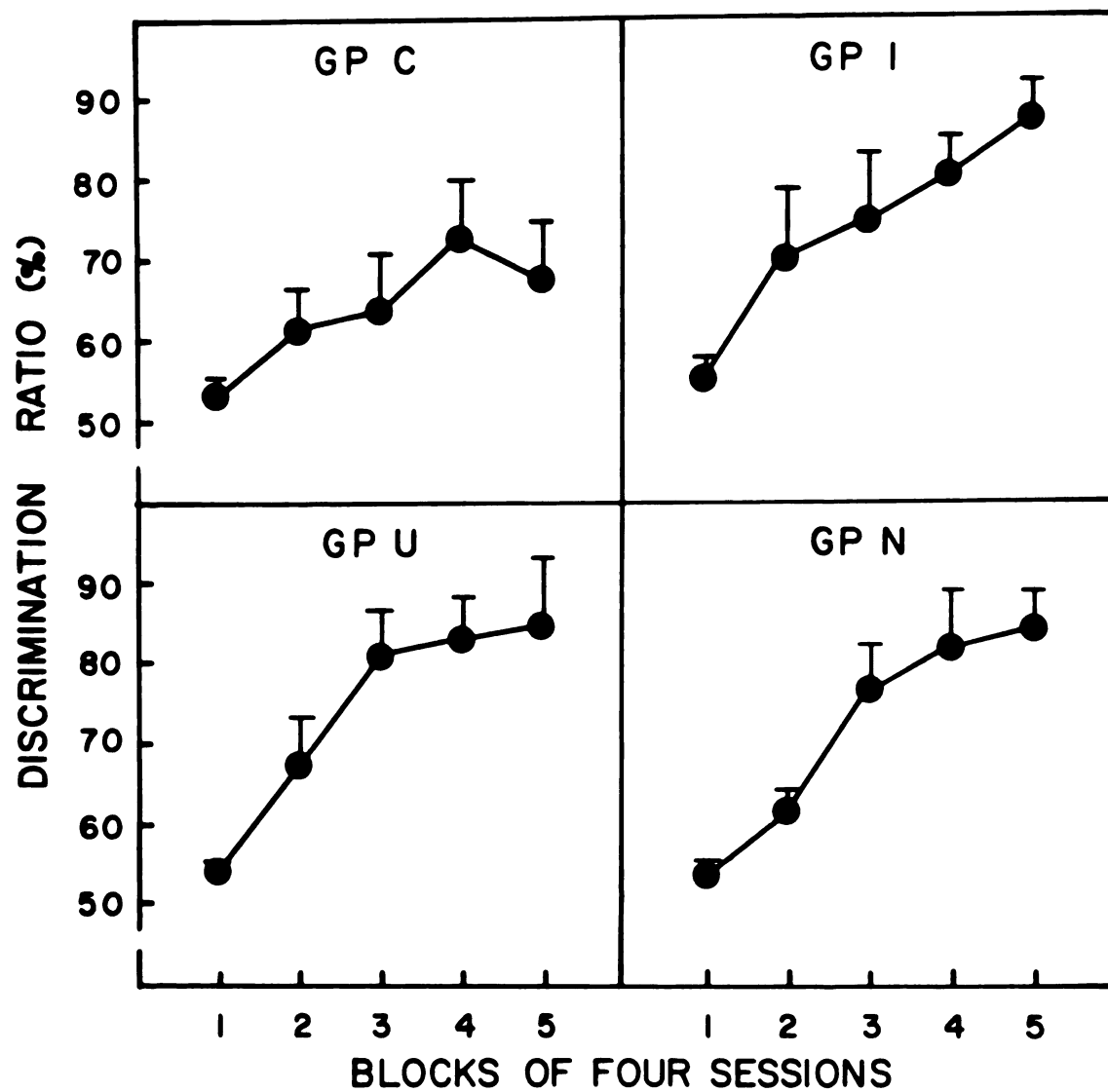
differences; at this stage of training Group I, Group C, and Group CN all were treated the same (except at the time of retraining when Group CN had no color matching training).

Phase II. Color Matching

Figure 2 shows the acquisition curves on the color matching task across the five blocks of four sessions. All groups show similar learning curves except for Group C, which failed to reach the higher ratios attained by the other three groups. One bird in Group C actually performed consistently below chance across the last three blocks of sessions (41%, 43%, and 40%). Excluding this bird the mean discrimination ratios are 67.4%, 78.2%, and 74.0% (compare to 63.0%, 72.3%, and 68.3% including this bird). Moreover, of the six birds in Group C, only three birds achieved discrimination ratios above 65%. In all groups, there was only one other bird that performed color matching so poorly (Bird 2847, Group N).

The birds in Group I all performed above 80% by the last block of sessions. This difference between the birds of Group C and Group I can not be attributed to training conditions, since up to this time both groups received identical conditions. For present purposes, the poor acquisition of Group C serves to highlight the quite good

Figure 2. Mean discrimination ratios of color matching training across the five blocks of four sessions. The T's over each data point indicate +1 standard error.



acquisition found in the next phase.

Phase III. Symbolic Matching

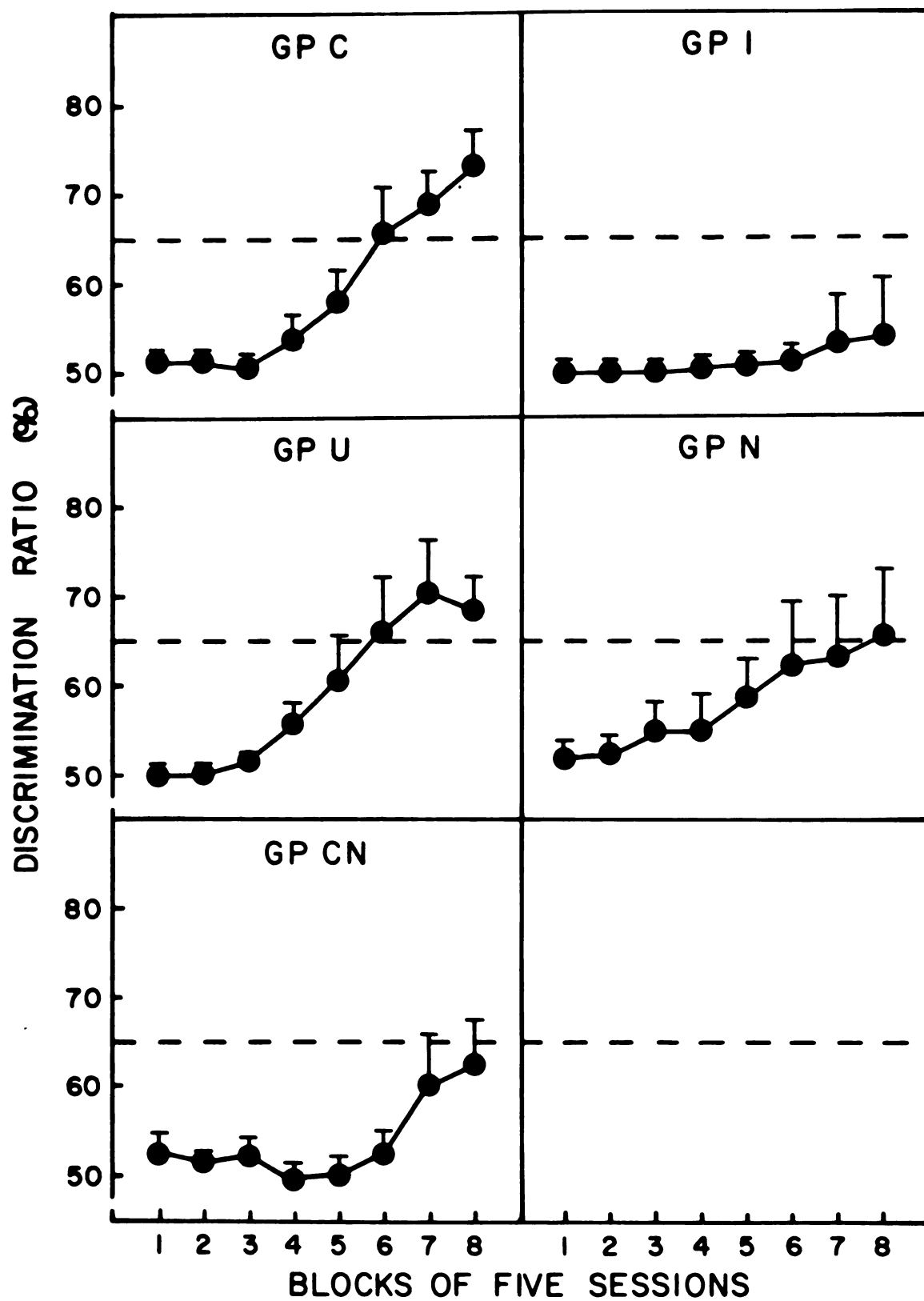
Figure 3 shows the acquisition curves of the five groups on the symbolic matching task across the eight blocks of five sessions. A split-plot factorial analysis of variance (Kirk, 1968) revealed that the main effect of Groups was not significant ($F(4,25)=2.35$, $p>.05$). However, there was a significant main effect of Sessions ($F(7,175)=24.44$, $p<.05$) and of the Sessions X Groups interaction ($F(28,175)=1.87$, $p<.05$).

Tukey's ratio (Kirk, 1968) was employed to test for significant differences between means selected according to the predictions of associatively-generated retrieval. There were three such predictions. First, it was predicted that Group C would show facilitated acquisition.

Second, inhibited acquisition was predicted for Group I. Third, since facilitation and inhibition were predicted as a result of the combined influence of serial conditioning and color matching, Group CN, without color matching training, was predicted to show neither facilitation or inhibition of acquisition of symbolic matching.

Visual inspection of Figure 3 shows that Group C reached the highest level of performance of all groups.

Figure 3. Mean discrimination ratios of symbolic matching training across the eight blocks of five sessions. The T's over each data point indicate ± 1 standard error.



However, when the mean of the last block of sessions of Group C was compared to Group N and Group U no significant differences were found (Group C, Group N: $q=1.82$, $p>.05$; Group C, Group U: $q=1.27$, $p>.05$), indicating no facilitation effect. Table 2 shows the mean discrimination ratios obtained by each bird on the last block sessions of the color matching task and the symbolic matching task. These data show that the birds in Group C, in general, performed poorly on the color matching task relative to the performance of the birds in Group N and Group U. Since the facilitation effect is necessarily a result of the combined influence of serial conditioning and color matching, poor learning of the color matching task would reduce the effect.

To test this possibility an Analysis of Covariance was performed using the Table 2 data of Group C, I, U, and N. The color matching ratios were the covariable. As expected, an overall significant difference was found ($F(3,19)=3.96$, $p<.05$) indicating that the between group differences in acquisition of symbolic matching were not eliminated by controlling for differences in color matching. Tests of simple effects, however, showed that Group C did not differ significantly from Group U ($q=2.04$, $p>.05$) nor from Group N ($q=2.21$, $p>.05$).

Table 2

Discrimination ratios for the last block of sessions on the color matching task and the symbolic matching task.

Group	Bird	Color Matching (%)	Symbolic Matching (%)
GpC	1285	85	75
	1056	96	86
	999	62	78
	49	62	54
	2925	40	71
	2923	65	72
GpI	5361	91	50
	1026	96	44
	1216	80	50
	874	88	71
	1834	87	53
	2798	92	55
GpU	1911	87	83
	1385	89	68
	2865	89	66
	10972	88	60
	5552	81	72
	5355	85	61
GpN	2847	64	56
	2884	91	86
	2940	83	51
	5562	94	57
	1409	90	87
	1133	84	64
GpCN	376	xx	58
	4573	xx	65
	1436	xx	46
	10759	xx	55
	2137	xx	82
	2967	xx	69

It is instructive to consider the symbolic matching mean ratios of these groups after adjusting for the color matching differences. The adjusted mean for Group C is 76.98, for Group U it is 66.93, and for Group N it is 66.11. Although these means failed to reach a statistically significant difference, the 10% difference between Group C and the other two groups certainly leaves open the possibility that had the birds in Group C learned color matching better, a facilitative effect may have been obtained.

Visual inspection of Figure 3 also shows that Group I performed at the worst level of all the groups, barely surpassing chance performance, in accordance with the predicted inhibition effect. This was supported statistically by finding that Group I performed significantly worse than Group C ($q(2,10)=3.43$, $p<.05$), and significantly worse than Group N during the last block of sessions ($q=3.95$, $p<.05$). Thus, the second prediction, that acquisition of the symbolic matching task by Group I would be inhibited, was supported.

Visual inspection of Figure 3 shows that the acquisition curve of Group CN lies between that of Group I and Group C in accordance with the third prediction, no facilitation or inhibition of acquisition for Group CN.

Statistical analysis reveals that Group CN did perform below the level of Group C on the last block of sessions ($q=3.34$, $p<.05$), but did not differ from Group I during these sessions ($q=2.43$, $p>.05$). However, the analysis is further complicated by the fact that Group CN did not differ from Group N ($q=1.52$, $p>.05$), which did differ from Group I as shown above. Interpretation of these statistical tests is therefore ambiguous; preusal of the individual birds' data is warranted.

Inspection of the symbolic matching data in Table 2 shows that three birds in Group CN approached or surpassed the 70% discrimination ratio (65%, 69%, and 82%) while three birds performed below 60% (46%, 55%, and 58%). However, in Group I, only one bird reached as high as 71%, one bird reached 55%, one, 53%, and the others were at or below chance (50%, 50%, and 44%). Thus, in Group CN four birds performed above 55% and in Group I only one bird did. The overall performances of the two groups are thus assumed to be in general agreement with the predictions that Group I would be inhibited and Group CN would not.

Discussion

Retrieval processes have been postulated to account for recent results in animal short-term memory (D'Amato & Worsham, 1974; Grant, 1980; Kendrick, Rilling, & Stonebraker, 1981; Medin, Reynolds, & Parkinson, 1980; Wagner, 1979). Of the two forms of retrieval described by Wagner (1979), self-generated retrieval and associatively-generated retrieval, the more interesting is the latter, because it claims that stimuli previously unrelated may, through learning, come to evoke memory of one another. Associatively-generated retrieval of stimulus representations was investigated in the current experiment to determine whether acquisition of delayed matching-to-sample by pigeons could be modulated by such a process. The results support this hypothesis.

Inhibition of acquisition via associatively-generated retrieval was supported. The acquisition curve of Group I indicated that virtually no learning was demonstrated by this group. Theoretically, it is proposed that the line sample stimuli of symbolic matching retrieved memories of the color stimuli with which they

were associated as a result of Phase I serial conditioning. Thus, the contents of memory at the time of the test were similar to the contents of memory on the previously learned color matching task. However, the outcome of the trials were reversed.

Consider one of the symbolic matching trials, for example, the horizontal-green trial. Presentation of the horizontal line sample stimulus effects retrieval of the memory of green by virtue of its previous association. Thus, in addition to the representation of the horizontal line, a representation of green is active in short-term memory when the green test stimulus is presented. In this sense the contents of short-term memory renders this trial similar to the previously-learned green-green color matching trial, to which the pigeon was conditioned to respond at high rates. Consistent with the previous conditioning of color matching, the pigeons of Group I responded at high rates during the green test stimulus of the horizontal-green trial of symbolic matching, but now the consequences are reversed and pecking was not reinforced. Thus, the pigeons failed to inhibit responding during the test stimuli on the negative trials, i.e., they failed to learn the symbolic matching task.

One alternative interpretation of the current data is based on the expectancies for food reinforcement created

by the three phases of training (DeLong & Wasserman, 1981; Peterson & Trapold, 1980; Trapold, 1970). It may be that expectancies of food reinforcement following green-horizontal and vertical-red are established by the serial conditioning. When the pigeons are presented with similar sequences they respond in accordance with the expectancies formed by serial conditioning.

For example, green-horizontal may have established an expectancy for food reinforcement in serial conditioning, and when presented with horizontal-green in symbolic matching the birds respond at high rates in expectancy of reinforcement. (The order of presentation of the stimuli were reversed between serial conditioning and symbolic matching to decrease the similarity between the two phases, thereby reducing the likelihood of the expectancy explanation.) This expectancy account is consistent with the performances of Group C and Group I, but fails to account for the poor learning of symbolic matching by Group CN. The only difference between Group CN and Group C was the absence of color matching in Group CN. The role of the expectancies formed during color matching is unclear, but it is difficult to see how the absence of such expectancies could produce the poor acquisition of Group CN. If anything the absence of additional expectancies should enhance the effects of serial

conditioning expectancies on acquisition of symbolic matching. The expectancy account does not provide an adequate account of the pattern of results obtained.

According to associatively-generated retrieval, color matching learning is crucial to produce the differences between Group C and Group I. Moreover, the poor learning of Group CN was accurately predicted by this retrieval hypothesis. The retrieval hypothesis does provide an adequate account of the results.

A second interpretation is a variation of the retrieval hypothesis. Assume that pigeons learn a generalized matching concept as a result of color matching training of the form "peck if two sequential stimuli are similar and do not peck if the two stimuli are dissimilar" (Carter & Werner, 1978; Holmes, 1979; Schrier & Thomas, 1980; Zentall & Hogan, 1975; 1978). Next consider the possibility that the color test stimuli of the symbolic matching task effect retrieval of representations of the associated line stimuli. For example, the green test stimulus retrieves a representation of a horizontal line. Thus, the horizontal-green trial is converted in memory into a horizontal-green plus horizontal trial, which may take advantage of the matching concept (horizontal-horizontal is a match) and produce facilitated acquisition in Group C, because this is a positive trial, and inhibi-

tion of acquisition in Group I, because this is a negative trial in violation of the matching concept. This account also predicts the obtained performances of the other groups. This account is, however, a different version of associatively-generated retrieval, rather than a competing hypothesis.

Facilitation of acquisition via associatively-generated retrieval was not clearly supported by the current data. There are two possible explanations for failing to detect facilitation. First, symbolic matching is a relatively difficult task for pigeons, requiring more sessions than true matching to attain similar performance levels (Carter & Werner, 1978; Cumming & Berryman, 1965). Any facilitation effect of associatively-generated retrieval may have been offset by the difficulty of the symbolic matching discrimination.

Second, the birds of Group C in general performed poorly on the color matching task relative to the performance of the birds in Group N and Group U. Since the facilitation effect is necessarily a result of the combined influence of serial conditioning and color matching, poor learning of color matching would reduce the effect. If all birds in Group C had learned the color matching task as well as the birds of Group U and Group N, the facilitation effect may have emerged.

The purpose here was to demonstrate that associatively-generated retrieval can influence delayed matching performance in pigeons; associatively-generated retrieval was found to be the source of interference with acquisition of delayed matching. Overall, the current data support an interactive view of the pigeon short-term memory and associative systems in which associated stimuli may retrieve representations of one another, thereby influencing the course of learning.

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