

TEMPORAL FACTORS INFLUENCING THE PIGEON'S
SUCCESSIVE MATCHING-TO-SAMPLE PERFORMANCE:
SAMPLE DURATION, INTERTRIAL INTERVAL,
AND RETENTION INTERVAL¹

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A successive matching-to-sample procedure that entails the sequential presentation of sample and test stimuli and the monitoring of response rates in a go/no-go discrimination of matching and nonmatching stimuli was studied as an alternative to the familiar delayed-matching paradigm of animal short-term memory. Three within-subject experiments studied the effects of sample duration (1 to 12 seconds), intertrial interval (5 to 50 seconds), and retention interval (1 to 50 seconds) on the pigeon's successive-matching performance. The results revealed that retention was (a) an increasing function of sample duration and intertrial interval, and (b) a decreasing function of retention interval. These results were in accord with those of more traditional short-term memory paradigms, and reveal the suitability of the successive-matching procedure for studying memory processes.

Key words: short-term memory, matching to sample, successive stimulus presentation, discriminative control, sample duration, intertrial interval, retention interval, key peck, pigeons

A substantial body of behavioral research during the last decade has been concerned with short-term memory in nonhuman subjects, memory being operationally defined as discriminative control of behavior by one or more external stimuli that are no longer present. Most research in animal short-term memory has used a small number of experimental paradigms, the most common being delayed-response and delayed matching-to-sample. One feature that both of these familiar paradigms share is that, following a retention interval, the subject is presented with two or more spatially distinct test stimuli (*i.e.*, a "correct" stimulus plus one or more "incorrect" comparison stimuli); the subject then chooses either the correct stimulus or an incorrect stimulus, and receives reinforcement only in the first instance.

D'Amato and Worsham (1974), Shimp and Moffitt (1977), and White (1974) trained animals with a different procedure. Rather than

requiring subjects to choose a correct stimulus from a set of stimuli including distractors, subjects were exposed to only one discriminative stimulus at the time of test. When the test stimulus was the same as the sample, subjects received reinforcement for making one manipulatory response (*e.g.*, responding to the left key); when the test stimulus was different than the sample, the subjects received reinforcement for making a different manipulatory response (*e.g.*, responding to the right key). This procedure of successive stimulus presentation avoids a possible confounding of retention loss with stimulus generalization effects between comparison and correct stimuli that is inherent in the classical matching procedure.

In 1959, Konorski proposed to study short-term memory with a related successive matching-to-sample paradigm. Here, one of two stimuli, S1 or S2, appears as the sample and, following a retention interval, one of the same two stimuli appears as the test stimulus. In Konorski's original procedure, reinforcement was available only on matching trials; the subjects received reinforcement on S1-S1 (S1 followed by S1) or S2-S2 trials, but not on S1-S2 or S2-S1 trials. The dependent variable in this successive-matching procedure is some relative measure of performance derived from the rate (or probability or amplitude) of response on matching and nonmatching trials.

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Wasserman (1976) studied a variant of Konorski's procedure for pigeons and noted several benefits of the successive-matching paradigm: (1) Tasks involving nonvisual stimuli, such as sounds or odors, are possible without stimulus interaction because only one stimulus is presented at a time. (2) Only one manipulandum is required (or none in a classical conditioning variant), eliminating possible contamination of the results by response position interference (Medin, 1976). (3) Reinforcement density remains constant throughout training and is not a function of matching accuracy. (4) Pigeons quickly acquire the delayed conditional discriminations required in this task (often within two weeks), in contrast with the more arduous course of learning frequently observed under other memory procedures.

Additional variants of the successive matching-to-sample procedure are possible. For example, symbolic matching-to-sample may be arranged by scheduling arbitrary relationships between the sample and test stimuli, which vary along different stimulus dimensions (Brodigan and Peterson, 1976; Carter and Eckerman, 1975; Cumming and Berryman, 1965; Looney, Cohen, Brady, and Cohen, 1977; Wilkie and Wilson, 1977). In one example of symbolic successive-matching, two colors, C1 and C2, may appear as sample stimuli and two line-tilt stimuli, L1 and L2, may appear as test stimuli. Reinforcement would be available only on C1-L2 or C2-L1 trials, but not on C1-L1 or C2-L2 trials. This procedure has the advantage over the matching-to-sample procedure that the subject may easily discriminate the sample from test stimuli (Carter and Eckerman, 1975).

The successive matching-to-sample procedure promises to be an important method of studying short-term memory in animals. However, before any analytical work can begin, it is necessary to compare the effects of several temporal parameters that have been obtained in the classical short-term memory paradigms with those obtained in the successive-matching procedure. Therefore, the present series of experiments studied the influence of retention interval (Experiments I, II, and III), intertrial interval (Experiment II), and sample stimulus duration (Experiment III) on successive-matching performance.

EXPERIMENT I

Most studies of short-term memory using choice-matching procedures (*e.g.*, Blough, 1959) have found that discriminative performance is a negative function of retention interval. Wasserman (1976) found that pigeons were capable of excellent discriminative performance in a successive-matching procedure when a single, 1-sec retention interval was used. In the present study, subjects were pre-trained on a successive-matching procedure with a 1-sec retention interval. Subsequent to this replication of Wasserman (1976), these subjects were administered a successive-matching procedure involving a range of retention interval values.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons, maintained at 80% of their free-feeding weights throughout training, were housed in individual cages with 24-hr room illumination. Grit and water were always available in the home cages. Subjects were not studied on days when their weight deviated by more than 10 g from the 80% value.

Apparatus

Four three-key pigeon conditioning chambers were used. In each, only the center key was operative. The 1.9-cm diameter plastic key required a force of at least 0.05 N for activation, and was positioned 9.4 cm above the solenoid-operated grain magazine and 4.9 cm below the houselight (28 V dc, CM 1820 bulb), which was encased in a black metal housing that directed light toward the ceiling. The pecking key could be transilluminated with either green or red light by means of a miniature display projector (IEE Series 10, 28-V dc, CM 1820 bulbs). The interior walls of the chamber and the response panel (which contained the response keys, houselight, and grain hopper) were constructed of aluminum. Masking noise was continually provided to the experimental room. In an adjoining room, scheduling of experimental sessions and data collection were managed by a DEC PDP 8/I minicomputer equipped with a relay interface and the SKED software system (Snapper, Stephens, and Lee, 1974).

Procedure

All subjects were initially autoshaped to peck the center key (both red and green illumination) of the pigeon chamber. Responses to the darkened side keys had no effect and were not recorded here or later. The birds then received from 121 to 127 pretraining sessions of successive matching-to-sample conditioning, with a constant 1-sec retention interval between the sample and test stimuli. Following a 25-sec intertrial interval, red or green light equiprobably transilluminated the center key. The first key peck after 5 sec terminated the sample light and initiated the 1-sec retention interval. Then, with equal probability, a red or green light was presented on the center key as the test stimulus. Reinforcement was available only on matching trials (red-red and green-green). On these matching trials, the first key peck after 5 sec turned off the keylight and the otherwise illuminated houselight, and initiated brief (2.50 sec) grain access. On nonmatching trials (red-green and green-red), the keylight and houselight extinguished automatically after 5 sec, resulting in a period of blackout equal in duration to food presentation time. In these and all subsequent successive-matching sessions, the birds received 100 daily trials.

The subjects were then shifted to the first phase of experimental training, entailing a multiple retention interval procedure. All of the experimental details were identical to single retention interval matching, except that for each trial the retention interval was randomly selected from the set of values: 1, 5, 10, and 25 sec. Phase I training lasted 45 days.

Two subjects (X0 and X1) then received additional training during Phase II. On alternate days, sessions were identical to those of the previous phase. The other half of the sessions involved retention intervals randomly selected on each trial from the set of values: 2, 8, 16, and 40 sec. This manipulation sought to determine if a subject's performance was a function of its having repeatedly received a single set of retention interval values. Phase II training lasted 30 days.

Dependent Variables

Mean response rates to both matching and nonmatching test stimuli were computed daily for each retention interval. For matching

trials, only pecks made during the first 5 sec of stimulus presentation were included in the rate calculations. For nonmatching trials, the test stimulus always terminated automatically after 5 sec. From these response rates, a discrimination index was computed for each retention interval by the following equation: $\text{discrimination index} = (\text{mean response rate on matching trials}) \div (\text{mean response rate on matching trials} + \text{mean response rate on nonmatching trials}) \times 100$. A discrimination index of 50 indicates chance performance. As performance improves, the index approaches 100. This index was employed to facilitate comparison of performance in the successive-matching task with the per cent correct performance measure used in the familiar choice-matching procedures. This single metric also allows one easily to assess discriminative performance between individual subjects whose absolute response rates may be quite different.

RESULTS

All subjects evidenced learning under the successive-matching procedure. The mean discrimination index for the three birds over the last 10 days of single retention interval pretraining was 89%. Figure 1 shows that when first shifted to multiple retention intervals in Phase I, performance at the 1-sec interval deteriorated sharply during the first five days, but then returned to its final single-interval level (dashed line) during the remaining 40 days. Performance at the 5- and 10-sec retention intervals continued to improve gradually throughout training.

Figure 2 shows that, when 2-, 8-, 16-, and 40-sec retention intervals were alternated with 1-, 5-, 10-, and 25-sec retention intervals on different days during Phase II, discriminative responding continued to be a monotonic function of retention interval. Thus, the performance improvements shown in Figure 1 during Phase I were probably not due to learning of the specific retention intervals that were administered.

Table 1 shows the effects of retention interval on the absolute rate of responding on matching and nonmatching trials during the first 5 sec of the test stimulus on the last 10 days of Phase I. The decrease in discriminative performance as a function of retention interval during multiple retention interval training was primarily the result of a large increase

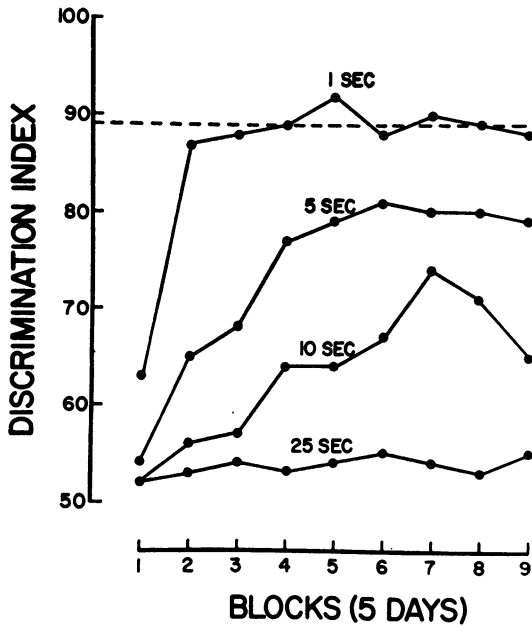


Fig. 1. Mean discrimination index at 1-, 5-, 10-, and 25-sec retention intervals as a function of five-day blocks of training during Phase I in Experiment I. The dashed line indicates mean performance at the 1-sec interval for the last 10 days of the previous single retention interval (pretraining) procedure.

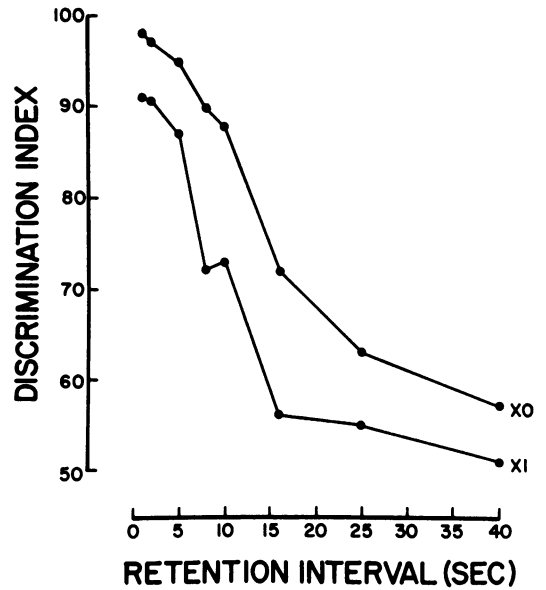


Fig. 2. Mean discrimination index as a function of retention interval for two subjects during Phase II of Experiment I. The data were averaged for all 30 days of training (15 days at each set of retention intervals; 1, 5, 10, and 25 sec and 2, 8, 16, and 40 sec).

in key-peck rate on nonmatching trials, although one subject (X2) also showed a marked and steady decline in response rate on matching trials.

EXPERIMENT II

Most research has found that increasing the amount of time between trials improves short-term memory performance (Herman, 1975; Holt and Schafer, 1973; Jarrard and Moise, 1971; Loess and Waugh, 1967; Maki, Moe, and

Bierley, 1977; Roberts, 1974). Some theorists (e.g., D'Amato, 1973) have even suggested that the duration of the intertrial interval may be a primary controlling variable of discriminative performance in matching-to-sample tasks. The present experiment studied the effects of varying the duration of the intertrial interval on successive-matching performance.

METHOD

Subjects

Two birds (X0, X1) from Experiment I served.

Table 1

Mean key-peck rate (pecks per second) and standard error for responses to matching (M) and nonmatching (N) test stimuli as a function of retention interval during Days 36 to 45 of Phase I in Experiment I.

| Subject | Retention Interval (sec) | | | | | | | |
|---------|--------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| | 1 | | 5 | | 10 | | 25 | |
| | M | N | M | N | M | N | M | N |
| X0 | 2.53 ±0.07 | 0.07 ±0.03 | 2.55 ±0.06 | 0.19 ±0.04 | 2.45 ±0.11 | 0.74 ±0.13 | 2.40 ±0.09 | 1.89 ±0.13 |
| X1 | 1.75 ±0.07 | 0.18 ±0.06 | 1.93 ±0.09 | 0.45 ±0.08 | 1.89 ±0.09 | 0.96 ±0.14 | 1.75 ±0.07 | 1.50 ±0.10 |
| X2 | 5.24 ±0.13 | 1.59 ±0.29 | 4.83 ±0.10 | 2.59 ±0.28 | 4.60 ±0.14 | 2.96 ±0.29 | 4.01 ±0.18 | 3.70 ±0.16 |

Apparatus

The apparatus was identical to Experiment I.

Procedure

All of the procedural details were identical to Experiment I except that the retention intervals were now 1, 10, 25, and 50 sec. Intertrial intervals of 5, 25, and 50 sec were varied between sessions in a random block design; each of the three values appeared once in each of the 10, three-day blocks. Training lasted 30 days.

RESULTS

As the intertrial interval was lengthened, discriminative performance improved at all retention intervals. The largest performance differences were evidenced between the 5- and 25-sec intertrial intervals at retention intervals of 1, 10, and 25 sec. In Figure 3, the mean discrimination indices over Days 1 to 30 are plotted for intertrial interval as a function of

retention interval (left panel), and for retention interval as a function of intertrial interval (right panel). Table 2 shows the corresponding response-rate data. Here, it is to be noted that increases in the intertrial interval generally led to higher response rates on matching trials and to lower response rates on nonmatching trials at 1-, 10-, and 25-sec retention intervals. Both trends contributed to enhanced discriminative performance.

EXPERIMENT III

This experiment studied the effects of varying sample stimulus duration on successive-matching performance. In general, previous work with classical short-term memory procedures has shown that retention is a positive function of the presentation time of the sample stimulus (Devine, Jones, Neville, and Sakai, 1977; Grant, 1976; Herman and Gordon, 1974; Leith and Maki, 1975; Maki and Leuin, 1972; Maki and Leith, 1973; Roberts, 1972; Roberts and Grant, 1974; Shimp, 1976b).

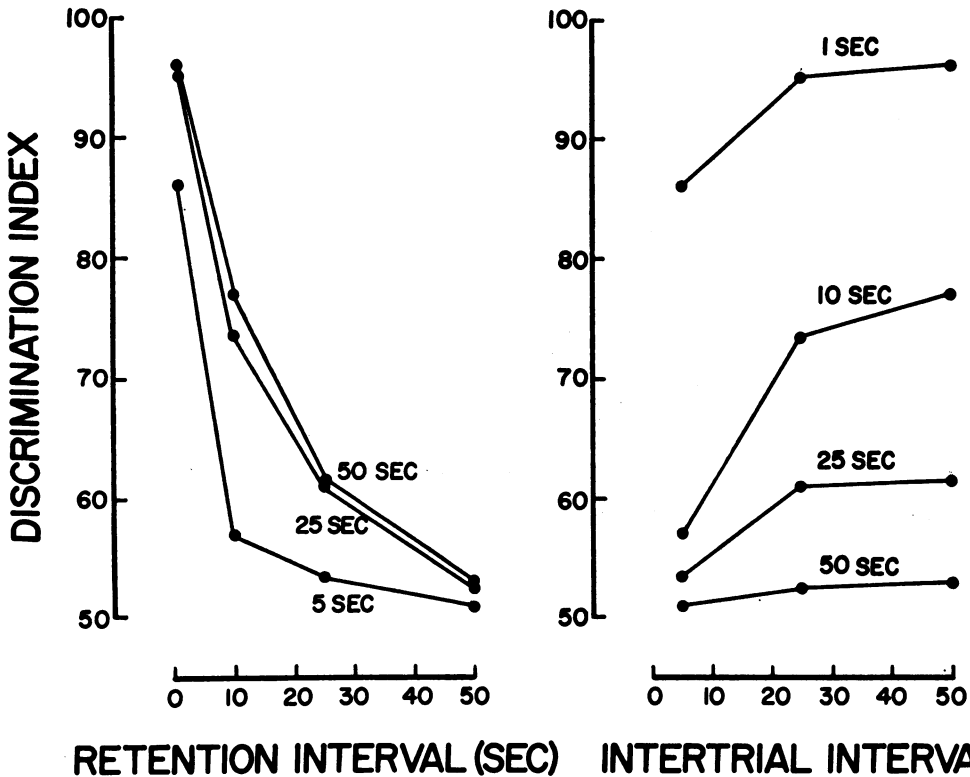


Fig. 3. Mean discrimination index at 5-, 25-, and 50-sec intertrial intervals as a function of retention interval (left panel), and for retention interval as a function of intertrial interval (right panel) in Experiment II. The data were averaged over all 30 days of training.

Table 2

Mean key-peck rate (pecks per second) and standard error for responses to matching (M) and nonmatching (N) test stimuli as a function of intertrial interval (ITI) during Days 1 to 30 in Experiment II.

| Subject | Retention Interval (sec) | | | | | | | |
|------------|--------------------------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | | 10 | | 25 | | 50 | |
| | M | N | M | N | M | N | M | N |
| 5-sec ITI | | | | | | | | |
| X0 | 2.31 | 0.30 | 2.12 | 1.61 | 1.91 | 1.70 | 1.80 | 1.75 |
| | ±0.06 | ±0.08 | ±0.09 | ±0.13 | ±0.09 | ±0.10 | ±0.10 | ±0.09 |
| X1 | 2.15 | 0.43 | 2.04 | 1.57 | 1.96 | 1.69 | 1.71 | 1.62 |
| | ±0.08 | ±0.07 | ±0.09 | ±0.10 | ±0.10 | ±0.11 | ±0.09 | ±0.11 |
| 25-sec ITI | | | | | | | | |
| X0 | 2.44 | 0.06 | 2.57 | 0.72 | 2.36 | 1.37 | 2.20 | 1.95 |
| | ±0.08 | ±0.02 | ±0.10 | ±0.11 | ±0.06 | ±0.11 | ±0.08 | ±0.07 |
| X1 | 2.20 | 0.19 | 2.34 | 1.05 | 2.32 | 1.63 | 2.00 | 1.88 |
| | ±0.08 | ±0.06 | ±0.07 | ±0.14 | ±0.09 | ±0.15 | ±0.10 | ±0.09 |
| 50-sec ITI | | | | | | | | |
| X0 | 2.44 | 0.04 | 2.57 | 0.55 | 2.34 | 1.41 | 2.27 | 1.94 |
| | ±0.08 | ±0.01 | ±0.08 | ±0.10 | ±0.08 | ±0.08 | ±0.08 | ±0.10 |
| X1 | 2.55 | 0.17 | 2.52 | 0.97 | 2.36 | 1.50 | 2.16 | 2.03 |
| | ±0.07 | ±0.04 | ±0.05 | ±0.14 | ±0.07 | ±0.18 | ±0.08 | ±0.10 |

For this experiment, naive subjects were administered a multiple retention interval procedure from the onset of training in order to determine the necessity of pretraining with a single, short retention interval.

METHOD

Subjects

Four experimentally naive domestic pigeons served as subjects. Animal care and deprivation conditions were identical to Experiments I and II.

Apparatus

The apparatus was the same as in Experiments I and II.

Procedure

The subjects received autoshaping pretraining with red and green keylight stimuli as in Experiment I. In contrast to the first experiment, however, these birds were then immediately switched to the multiple retention interval procedure of Experiments I and II. Sixty sessions were conducted in a random block design with sample duration values of 1, 3, 6, and 12 sec varied between sessions; each of the four values appeared once in each of 15, four-day blocks. Retention intervals of 1, 10, 25, and 50 sec were randomly varied within each

session. The duration of food access was reduced from 2.50 sec to 1.75 sec during Experiment III to prevent the birds from "overeating" during an experimental session.

RESULTS

All birds evidenced learning of the matching task within the first 10 days of training. Performance continued improving until about Day 40, and then remained at an asymptotic level from Days 41 to 60. Figure 4 shows the mean discrimination indices over Days 41 to 60 plotted for sample stimulus duration as a function of retention interval (left panel), and for retention interval as a function of sample stimulus duration (right panel). The corresponding response-rate data are shown in Table 3.

For a sample duration of 1 sec, very little was remembered at any retention interval. At sample durations of 3 sec or longer, discriminative responding was an orderly increasing function of sample presentation time. Table 3 shows that both a decrease in response rate on matching trials and an increase in response rate on nonmatching trials contributed to the loss of discrimination as the retention interval was increased. No correspondence was observed between response rates on matching test stimuli and sample stimulus duration; however, response rates on nonmatching trials

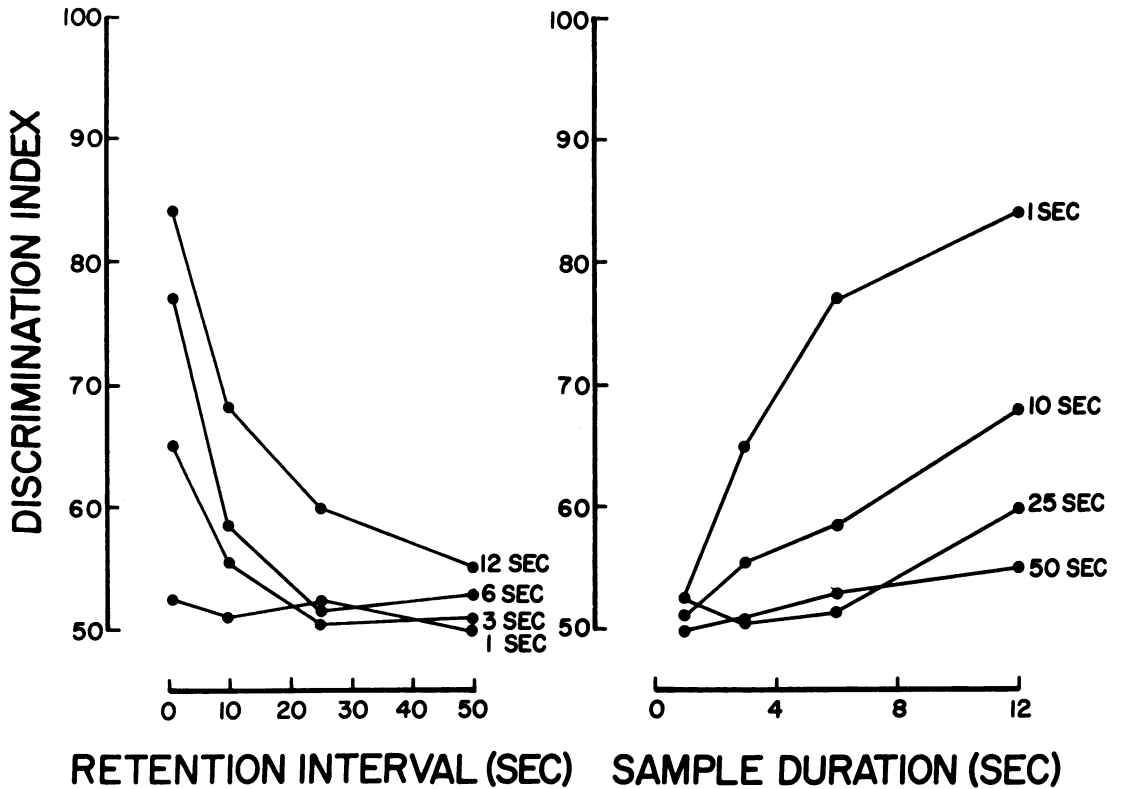


Fig. 4. Mean discrimination index for 1-, 3-, 6-, and 12-sec duration sample stimuli as a function of retention interval (left panel), and for retention interval as a function of sample duration (right panel) in Experiment III. The data were averaged over the last 20 days of training.

were a negative function of sample duration, thus being the main contributor to the observed effect of sample duration on discriminative performance.

GENERAL DISCUSSION

The present results reveal the suitability of the successive matching-to-sample paradigm for studying animal memory. In Experiments I, II, and III, retention of the sample stimulus was a negative function of the time since its presentation. Retention was a positive function of the duration of the intertrial interval in Experiment II, and of the presentation time of the sample stimulus in Experiment III. Interestingly, the birds in Experiment III were trained with multiple retention intervals immediately after brief autoshaping pretraining. Apparently, initial training with a single, short retention interval is not necessary for pigeons to learn to match-to-sample (see Berryman, Cumming, and Nevin, 1963 for earlier unsuccessful data).

When birds were shifted from a procedure involving a single, 1-sec retention interval to one involving multiple retention intervals in Experiment I, performance at the 1-sec interval deteriorated abruptly, and then recovered within five days to preshift levels. It would be interesting to know how this brief generalized disruption compares with that arising in choice-matching procedures. In the choice-matching situation, a decrement in correct responding would result in a corresponding decrease in reinforcement density; this change in reinforcement density could prolong the disruptive influence of added, long retention intervals. After the introduction of longer retention intervals in Experiment I, performance at some of these added intervals (10 and 25 sec) also improved as training progressed, although the improvement was more gradual and protracted than at the 1-sec retention interval. The significance of this fact remains to be determined. One possibility is that subjects are learning to respond differentially to new internal representations of the sample

Table 3

Mean key-peck rate (pecks per second) and standard error for responses to matching (M) and nonmatching (N) test stimuli as a function of sample stimulus duration (SD) during Days 41 to 60 in Experiment III.

| Subject | Retention Interval (sec) | | | | | | | |
|-----------|--------------------------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | | 10 | | 25 | | 50 | |
| | M | N | M | N | M | N | M | N |
| 1-sec SD | | | | | | | | |
| 1 | 2.59 | 2.34 | 2.05 | 2.04 | 2.10 | 2.09 | 2.00 | 2.06 |
| | ±0.09 | ±0.11 | ±0.39 | ±0.12 | ±0.12 | ±0.10 | ±0.06 | ±0.10 |
| 2 | 1.36 | 1.35 | 1.89 | 1.71 | 1.62 | 1.46 | 1.37 | 1.67 |
| | ±0.22 | ±0.12 | ±0.19 | ±0.19 | ±0.24 | ±0.23 | ±0.23 | ±0.21 |
| 3 | 3.69 | 3.56 | 3.48 | 3.51 | 3.48 | 3.56 | 3.53 | 3.63 |
| | ±0.08 | ±0.08 | ±0.09 | ±0.08 | ±0.05 | ±0.09 | ±0.07 | ±0.08 |
| 4 | 1.69 | 1.33 | 0.81 | 0.75 | 0.77 | 0.56 | 0.53 | 0.49 |
| | ±0.14 | ±0.17 | ±0.09 | ±0.06 | ±0.08 | ±0.08 | ±0.04 | ±0.07 |
| 3-sec SD | | | | | | | | |
| 1 | 2.54 | 1.36 | 2.23 | 1.87 | 2.01 | 2.16 | 2.05 | 1.99 |
| | ±0.06 | ±0.20 | ±0.06 | ±0.09 | ±0.09 | ±0.08 | ±0.06 | ±0.10 |
| 2 | 1.85 | 1.08 | 2.05 | 1.31 | 1.52 | 1.45 | 1.45 | 1.44 |
| | ±0.21 | ±0.12 | ±0.17 | ±0.12 | ±0.20 | ±0.18 | ±0.16 | ±0.21 |
| 3 | 3.83 | 1.66 | 3.63 | 3.54 | 3.46 | 3.44 | 3.58 | 3.60 |
| | ±0.06 | ±0.27 | ±0.04 | ±0.11 | ±0.06 | ±0.13 | ±0.06 | ±0.05 |
| 4 | 2.09 | 1.24 | 0.92 | 0.72 | 0.63 | 0.55 | 0.49 | 0.45 |
| | ±0.21 | ±0.19 | ±0.15 | ±0.11 | ±0.10 | ±0.11 | ±0.07 | ±0.07 |
| 6-sec SD | | | | | | | | |
| 1 | 2.48 | 0.68 | 2.17 | 1.47 | 1.82 | 2.09 | 1.84 | 1.90 |
| | ±0.06 | ±0.12 | ±0.11 | ±0.15 | ±0.07 | ±0.09 | ±0.11 | ±0.08 |
| 2 | 2.08 | 0.60 | 2.19 | 1.38 | 1.63 | 1.37 | 1.49 | 1.27 |
| | ±0.23 | ±0.07 | ±0.10 | ±0.08 | ±0.20 | ±0.15 | ±0.21 | ±0.26 |
| 3 | 4.06 | 0.66 | 3.87 | 3.33 | 3.60 | 3.31 | 3.61 | 3.49 |
| | ±0.09 | ±0.16 | ±0.07 | ±0.19 | ±0.07 | ±0.08 | ±0.06 | ±0.12 |
| 4 | 2.19 | 1.06 | 1.05 | 0.73 | 0.72 | 0.63 | 0.56 | 0.43 |
| | ±0.19 | ±0.23 | ±0.13 | ±0.16 | ±0.12 | ±0.08 | ±0.07 | ±0.06 |
| 12-sec SD | | | | | | | | |
| 1 | 2.33 | 0.29 | 2.04 | 0.75 | 1.90 | 1.29 | 1.84 | 1.61 |
| | ±0.06 | ±0.13 | ±0.06 | ±0.16 | ±0.10 | ±0.18 | ±0.12 | ±0.09 |
| 2 | 2.01 | 0.34 | 2.17 | 0.85 | 1.60 | 0.99 | 1.25 | 1.09 |
| | ±0.14 | ±0.10 | ±0.19 | ±0.13 | ±0.13 | ±0.08 | ±0.14 | ±0.19 |
| 3 | 4.42 | 0.48 | 4.07 | 1.91 | 3.68 | 2.75 | 3.60 | 2.98 |
| | ±0.16 | ±0.22 | ±0.10 | ±0.33 | ±0.08 | ±0.22 | ±0.09 | ±0.11 |
| 4 | 1.96 | 0.77 | 0.98 | 0.65 | 0.65 | 0.43 | 0.55 | 0.40 |
| | ±0.20 | ±0.23 | ±0.13 | ±0.13 | ±0.10 | ±0.09 | ±0.10 | ±0.06 |

stimulus resulting from weakened afferent traces that accompany longer retention intervals (see ahead).

D'Amato and Cox (1976) argued that, because performance in animal short-term memory tasks improves consistently throughout training, the kind of memory studied with matching-to-sample procedures is different than human short-term memory. For this and other reasons, D'Amato and Cox proposed that matching-to-sample and related memory performance in animals is based on temporal discrimination processes, rather than on the hypothesized processes underlying human memory. According to the temporal discrimi-

nation hypothesis, a subject need never forget a prior event. Instead, performance decrement as a function of retention interval is due to the animal's failure to discriminate which one of a set of stimuli has been most recently presented. The difficulty of this temporal discrimination is expressed as a ratio of the time since the sample on the prior trial divided by the time since the sample on the current trial: the discrimination becoming easier as the value of the ratio increases.

If a subject does not forget the sample stimulus, then parametric manipulation of sample stimulus duration should have little effect when varied over a range of values. D'Amato

and Worsham (1972) found no effect of sample stimulus durations between 75 and 450 msec, and interpreted this result as support for the temporal discrimination hypothesis. However, most research has shown that short-term memory in animals is facilitated by increasing the presentation time or the number of repetitions of the sample stimulus. To reconcile this fact with the temporal discrimination hypothesis, one might argue that increased presentation time of the sample stimulus enhances its discriminability (Staddon, 1972). Unfortunately, this added assumption detracts from the appealing parsimony of the unembellished hypothesis. Furthermore, Experiment III found that increasing sample duration facilitated the pigeon's matching performance even after 60 days of exposure to the same procedure, thus rendering unlikely D'Amato's (1973) proposal that increasing the duration of the sample will have an effect only if the stimulus materials are unlearned.

If changes in the duration of the sample stimulus enhance the discriminability of that stimulus, then there are at least two possible hypotheses of how this enhancement could occur. First, the duration of the sample stimulus may be encoded as an additional stimulus attribute that could aid in the memory of that sample. Since both the test stimuli and the sample stimuli were red or green keylights in the present experiments, the test stimulus on trial $n-1$ constituted the event most likely to impair discrimination of the sample stimulus as "most recent" at the time of test on trial n . Thus, in Experiment III, matching performance should have been better at sample duration values of 1 or 12 sec than at 3 or 6 sec, because the former two values differed from the 5-sec test duration more than the latter two values. Clearly, the present results did not support this hypothesis (see Figure 4). The second possibility is that discriminability of the sample stimulus is a direct increasing function of its duration. This hypothesis is overwhelmingly supported by the data. However, adding this assumption to the temporal discrimination hypothesis may preclude differentiating this hypothesis from other theoretical accounts of short-term memory processes (see ahead).

A different interpretation of animal short-term memory has been advanced by Grant and Roberts (1973; Roberts and Grant, 1974, 1976).

This theory axiomatically assumes that different stimulus events are stored as independent memory traces. The growth of any trace is assumed to be a negatively accelerated function of stimulus presentation time or the number of repetitions of the sample. Retention loss is a function both of negatively accelerated trace decay and of competition from any active traces of previous, different stimuli. Thus, this stimulus trace hypothesis predicts that increasing sample presentation time should facilitate short-term memory, in accord with most available data.

Both the temporal discrimination hypothesis and the stimulus trace hypothesis predict that increasing the intertrial interval will facilitate matching performance: in the former case by facilitating the temporal discrimination through making the sample $n-1$ -to-test interval long relative to the sample n -to-test interval, and in the latter case by allowing more time for competing stimulus traces to decay. We found in Experiment II that increases in the intertrial interval from 25 to 50 sec had little influence on matching performance. Such a result is quantitatively in keeping with a trace decay interpretation; since little was remembered at 25- and 50-sec retention intervals (see Figures 3 and 4), little proactive interference should have arisen from prior stimuli at these temporal values.

It is not yet clear whether the temporal discrimination hypothesis and the stimulus-trace hypothesis are competing or complementary. A better understanding of the controlling variables of matching-to-sample performance will facilitate the analysis of the processes and organizational rules of memory-dependent behavior (Shimp, 1976a). As Mason and Wilson (1974) suggested, "what was it" may not be a distinct question from "when was it last seen". Analytical work with the successive matching-to-sample paradigm is currently in progress in our laboratory to help clarify these unresolved issues.

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