

## Pigeons' Memory for Event Duration: Differences between Choice and Successive Matching Tasks

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Two experiments examined memory for event duration in pigeons using choice and successive matching tasks. In the choice task, two stimuli were presented following the sample, and the correct choice depended upon the duration of the preceding sample. In the successive task, only one of two stimuli was presented following the sample, and whether responding was or was not reinforced depended upon the duration of the preceding sample. In the first experiment, a successive matching task was employed and accuracy decreased at an equivalent rate as a function of delay on short-sample and long-sample trials, regardless of whether the events which differed in duration were samples of houselight or food. The second experiment, which employed as samples different durations of houselight, replicated this result both in naive subjects and in subjects previously trained in a choice matching task. In addition, it was found that naive subjects which were trained and tested in a choice matching task demonstrated a more rapid decrease in accuracy on long-sample trials than on short-sample trials as a function of delay; a result which has been obtained in several previous studies and has been referred to as the "choose-short" effect. It was also found, however, that the choose-short effect did not occur in the choice matching task if subjects had been trained and tested previously in the successive matching task. It was concluded that pigeons employ different coding strategies in matching to sample duration in the choice and successive tasks. © 1991 Academic Press, Inc.

Two general types of memory tasks have been used to assess short-term retention of event duration in pigeons. One is choice matching-to-sample in which two (or more) choice stimuli are presented following termination of a sample stimulus. The correct choice depends on the duration of the preceding sample. Choice of the correct stimulus is rein-

The research was supported by grants from the Natural Sciences and Engineering Research Council of Canada to the authors (A0443 to D.S.G. and OGP0038861 to M.L.S.). Each author contributed equally and order of authorship was determined by tossing a coin. Requests for reprints may be addressed to either author at the Department of Psychology, University of Alberta, Edmonton, Alberta, Canada T6G 2E9.

forced (usually with food) and choice of an incorrect stimulus results in termination of the trial without reinforcement. Memory for sample duration is assessed in terms of choice accuracy (e.g., Kraemer, Mazmanian, & Roberts, 1985; Spetch & Wilkie, 1983). In this task, animals tend to make systematic errors when the delay between the event and choice period is increased: Both rats (Church, 1980) and pigeons (e.g., Spetch & Wilkie, 1982) make a disproportionate number of responses appropriate to the short sample when the delay is increased. This "choose-short effect" has now been reported in a number of experiments (Kraemer *et al.*, 1985; Spetch, 1987; Spetch & Rusak, 1989; Spetch & Wilkie, 1982, 1983), and occurs with samples of either food duration or light duration.

The second type of task used to assess memory for duration is the successive matching-to-sample procedure (Parker & Glover, 1987; Wasserman, DeLong, & Larew, 1984). In this task there are two different test stimuli but only one of them is presented following the sample on each trial. Pecks to one test stimulus are reinforced following short samples but not following long samples, whereas pecks to the other test stimulus are reinforced following long samples only. Memory is assessed by differential pecking to the conditional positive stimulus (S+) and negative stimulus (S-) following a delay interval.

This successive procedure has been employed in two studies of pigeons' memory for event duration (Parker & Glover, 1987; Wasserman *et al.*, 1984). In the Wasserman *et al.* experiment, pecks to a vertical-line test stimulus were reinforced following key-light samples of 1, 2, 3, or 4 s, and pecks to a slanted-line test stimulus were reinforced following key-light samples of 5, 6, 7, or 8 s. Two pigeons were tested with delays ranging from 1 to 8 s. Discrimination decreased at the longer delays but the birds showed no systematic tendency to respond more to the S+ for short samples than to the S+ for long samples (an effect that would be analogous to the choose-short effect that appears in the choice task). In the study by Parker and Glover, only overall discrimination ratios were reported so it is not possible to determine whether their pigeons displayed a tendency to respond more to the S+ for short samples as the delay was increased.

The choice and successive tasks would seem to involve similar memory requirements. In the choice task the pigeon must in some fashion remember the duration of the preceding sample over the delay interval in order to accurately select the correct choice stimulus. In the successive task the pigeon also must remember the sample duration in some way over the delay in order to determine whether the test stimulus presented is an S+ or an S-. With color or form samples, the results of a variety of manipulations have been similar in the two procedures (e.g., Nelson & Wasserman, 1978), and it has generally been assumed that similar

memory processes operate in the two procedures. One would therefore expect that the response of pigeons to variations in the delay interval with event duration samples would be similar in the two tasks.

### EXPERIMENT 1

In Experiment 1 we examined the effect of varying delay intervals on pigeons' memory for event duration within the successive matching-to-sample procedure. In particular, we sought to determine whether pigeons would show a tendency to respond in accord with the contingencies of short-sample trials as the delay is increased, as they do in the choice task (Spetch & Wilkie, 1982). Initially, four pigeons were trained and tested on the successive procedure, first with samples of light duration, and subsequently with samples of food duration. In a subsequent replication, four additional naive pigeons were trained and tested in the successive procedure with food-duration samples.

#### Method

##### *Subjects*

Eight adult White King pigeons served in this experiment, four in an original study (Group A), and four in a subsequent replication (Group B). The four pigeons in Group A had previously served in an experiment using a delayed choice-matching procedure with colors as the sample stimuli. Pigeons in Group B were experimentally naive at the start of this experiment. Mixed grain obtained primarily during experimental sessions maintained the birds at 85 to 90% of their free-feeding weights. The birds were housed in individual wire-mesh cages with water and grit freely available.

##### *Apparatus*

The experimental environment consisted of Grason-Stadler animal chambers that contained three horizontally aligned response keys, each requiring a force of about .25 N to operate. The keys could be transilluminated with white, red, or blue light by stimulus projectors mounted behind each key. The grain feeder was located below the center key, and grain presentations were accompanied by illumination of a lamp in the feeder. A 4.8-W houselight was centered at the top of the response panel. Experimental contingencies and data recording were controlled by a PDP-8e computer located in an adjacent room.

##### *Procedure*

*Preliminary training.* The naive birds first received one or two sessions of magazine training. Prior to training on the baseline task, all birds received a few sessions with an autoshaping procedure to peck red and

blue fields on the center key. Autoshaping continued until they reliably pecked both colors.

*Group A: Training and delay testing.* The 0-s delay successive matching-to-sample training entailed the following procedure. Trials began with illumination of the houselight as the sample stimulus. On half of the trials the sample duration was 2 s (short); on the remaining trials it was 10 s (long). Immediately following sample termination the center key was illuminated with a red or blue test stimulus. One color was positive for short, the other was positive for long; this designation was counterbalanced across subjects. Each of the four types of trials (two sample durations by two test stimuli) occurred three times in each block of 12 trials, with order randomly determined within blocks. If the test stimulus was positive, the first peck after 6 s produced 4-s access to grain as reinforcement. If the test stimulus was negative it terminated after 6 s without reinforcement. Trials were separated by a 45-s intertrial interval (ITI) during which the chamber was dark. Sessions were conducted 5 or 6 days per week at approximately the same time each day. Each session contained 48 trials.

Baseline training continued until the overall discrimination ratios (pecks on positive trials/total pecks) were .80 or higher for five consecutive sessions. Four birds met this criterion within 45 sessions. (One additional bird was initially trained for this experiment but failed to meet the accuracy criterion within 55 sessions and was not continued in the experiment.)

The birds next received five sessions of variable delay testing in which the 0-s delay occurred on half of the trials and 5-s and 10-s delays occurred equally often on the remaining trials. The order of delays was randomly determined for each session, but with the constraint that there be an equal number of short-sample and long-sample trials at each delay. Because their discrimination ratios dropped quite dramatically on the 0-s delay trials when these longer delays were introduced, the birds were placed back on baseline training until discrimination levels improved (from 5 to 10 sessions). When delay testing was reinitiated, the long delays were decreased and presented on fewer trials in each session. Thus, for the next 10 sessions of delay testing the 0-s delay occurred on 75% of the trials and 3-s and 9-s delays occurred equally often on the remaining trials.

After this delay testing phase, the birds were given 0-s delay training with food duration as the sample stimulus instead of light. The short sample continued to be 2 s but the long sample was changed to 8 s. Otherwise all aspects of the procedure were the same as those used during the original baseline training. The birds were trained with food-duration samples until their discrimination ratios were .80 or higher for five consecutive sessions. All birds achieved this criterion within 20 sessions. The birds then received 10 sessions of variable delay testing with 0-s delays on 75% of the trials, and 3-s and 9-s delays on the remaining trials.

In a final test phase the birds were given two no-sample test sessions.

Seventy-five percent of the trials were 0-s delay baseline trials with short and long food samples. On the remaining 25% of the trials the sample was omitted: The red or blue test stimulus was presented immediately after the ITI. A randomly selected half of these no-sample trials were arbitrarily designated as "short" trials and the reinforcement contingencies in effect were those that normally occurred following short samples. On the remaining no-sample trials the reinforcement contingencies appropriate to long samples were in effect.

**Group B. Training and testing.** The successive matching-to-sample training procedure used for this group was identical to that used for Group A, except that from the outset the samples were 2-s and 8-s presentations of food, and the test stimulus schedules were 5 s (if the test stimulus was positive, the first peck after 5 s produced reinforcement; if the test stimulus was negative, it terminated after 5 s and no reinforcement was presented). The birds were trained with the 0-s delay until they reached an accuracy criterion of .80 or better for five consecutive sessions. All birds met this criterion within 35 sessions. They then received 20 sessions of variable delay testing in which the 0-s delay occurred on 75% of the trials, and 5-s and 10-s delays occurred equally often on the remaining trials. The order of trials was randomly determined for each session, with the constraint that there be an equal number of short-sample and long-sample trials at each delay. Two birds required five retraining sessions with the 0-s delay only between their fifth and sixth delay-testing sessions because their discriminations deteriorated on all trials when delay testing was first initiated. Following delay testing, each bird received two no-sample test sessions, as described for Group A.

For all statistical analyses, the criterion for rejection of the null hypothesis was set at  $p < .05$ .

### Results

The top panel of Fig. 1 shows the results of the delay manipulation tests for Group A. The scores show mean discrimination ratios (pecks on positive trials/total pecks), multiplied by 100, on short-sample and long-sample trials as a function of delay, for the last 10 sessions of delay testing with light samples, and for the 10 sessions of delay testing with food samples. In both cases, discrimination ratios decreased as a function of delay, but the birds did not show a uniform tendency to respond at a higher rate to the S+ for short samples than to the S+ for long samples when the delay was lengthened.

This was confirmed by repeated-measures ANOVAs. For the light sample condition, the analysis revealed a significant effect of delay,  $F(2, 6) = 23.98$ , but neither the main effect of sample duration nor the Delay by Sample Duration interaction was significant (both  $F_s < 1$ ). Similarly, for the food sample condition, there was a significant effect of delay,  $F(2,$

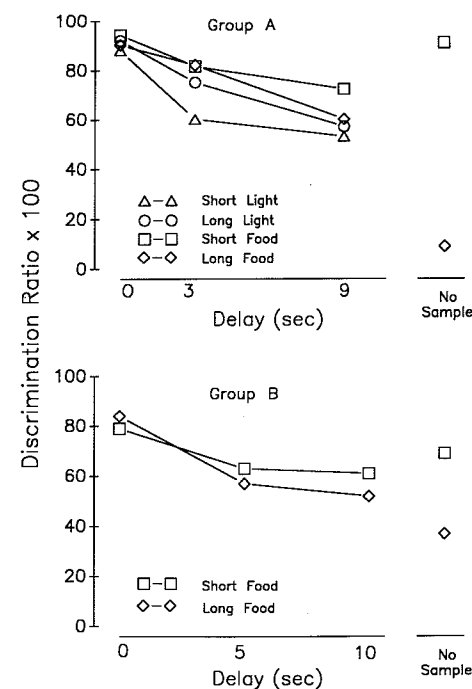


Fig. 1. Accuracy of matching to short and long samples as a function of delay during testing within the successive matching procedure in Experiment 1. The top portion shows accuracy in Group A which was tested with different durations of houselight and food. The bottom portion shows accuracy in Group B which was tested with different durations of food only. Performance on no-sample trials is shown in the right-most portion of the figure.

6) = 81.93, but not of sample duration,  $F(1, 3) = 1.27$ . The Delay by Sample Duration interaction was not significant,  $F(2, 6) = 2.17$ .

The bottom panel of Fig. 1 shows the results of the delay manipulation tests for the replication with naive subjects (Group B). Although the mean discrimination ratios indicated that discrimination ratios were slightly higher on short-sample trials than on long-sample trials at the 10-s delay, this was not consistent across birds. Moreover, the ANOVA revealed only a significant effect of delay,  $F(2, 6) = 61.17$ . Neither the main effect of sample duration,  $F < 1$ , nor the Delay by Sample Duration interaction,  $F(2, 6) = 3.15$ , was significant.

The right-hand portions of Fig. 1 show the results of the no-sample tests. These scores indicate the discrimination ratios that were obtained on the no-sample trials that were arbitrarily assigned the reinforcement contingencies for "short" or "long." A tendency to respond at higher rates to the test stimulus that was positive for short samples was displayed by all birds on these no-sample trials. Repeated-measures  $t$  tests confirmed

that discrimination ratios for "short" were significantly higher than discrimination ratios for "long," both for Group A,  $t(3) = 10.55$ , and for Group B,  $t(3) = 3.23$ .

### Discussion

The effect of delay manipulations on pigeons' memory for duration within the successive matching-to-sample task does not seem to parallel that typically observed in choice matching-to-sample tasks. In choice tasks, pigeons typically show a much steeper decline in accuracy on long-sample trials than on short-sample trials as a function of delay. And with delays that are considerably longer than the training value, the pigeons respond primarily in accord with the contingencies for short samples (e.g., Spetch & Wilkie, 1982, 1983). Analogous effects of delay on discrimination ratios did not emerge in the present experiment with the successive matching-to-sample procedure. Instead, discrimination ratios declined nondifferentially on short- and long-sample trials as a function of delay. Yet on trials in which the sample was omitted, the birds did show uniformly higher response rates to the positive test stimulus for short. This latter effect is analogous to the choose-short tendency that animals typically display in choice tasks when tested with no sample (e.g., Church, 1980; Spetch & Wilkie, 1983).

The difference between the results obtained here with the successive procedure and those obtained in previous experiments with the choice procedure suggests that delays have quite different effects on performance in these two tasks. This possibility was directly investigated in Experiment 2.

## EXPERIMENT 2

Given the limitations of conclusions based solely on between-experiment comparisons, the present experiment compared the effects of retention interval length on memory for event duration in the choice and successive procedures directly. This was accomplished, in part, by employing two independent groups of pigeons. One group was trained and subsequently tested with delays using a successive matching task. The other group was trained and subsequently tested with delays using a choice matching task. If the nature of the assessment task is a critical determinant of whether longer delays cause pigeons to respond in accord with the contingencies of short-sample trials, then a between-group comparison should reveal differences in the effect of increasing delay on accuracy. Specifically, prior research employing the choice procedure leads to the expectation that pigeons in the choice matching group will display a strong tendency to select the comparison stimulus associated with the short sample at longer delays. The results of the first experiment suggest that pigeons in the successive group will not display a marked tendency to respond prefer-

entially to the test stimulus associated with the short sample at longer delays.

The present experiment also provided a within-subject evaluation of the role of assessment procedure in determining whether pigeons tend to respond in accord with the contingencies of short-sample trials at longer delays. Following original training and testing, pigeons originally assigned to the successive task were trained and tested using a choice matching task, and pigeons originally assigned to the choice task were trained and tested using a successive matching task. If the type of assessment task is the critical determinant of whether pigeons respond in accord with the contingencies of short-sample trials at longer delays, then in the second phase, pigeons in the successive-then-choice group should display a choose-short effect at longer delays whereas pigeons in the choice-then-successive group should not display a respond-short effect at longer delays.

## Method

### Subjects

Eight naive, adult Silver King pigeons were reduced to and maintained at 80% of their free-feeding weight throughout the experiment. At the time of arrival in the laboratory, four birds were assigned at random to the successive procedure and the remaining four were assigned to the choice procedure.

### Apparatus

Four identical chambers were employed. One bird from each group was trained and tested in each of the four chambers. Three pecking keys were mounted horizontally in a row 20-cm above the floor in each chamber. An Industrial Electronics, Inc., in-line projector was mounted behind each key and was used to project stimuli onto the pecking key. A grain feeder was mounted below the center pecking key. Each test chamber was enclosed in a sound- and light-attenuating enclosure. Masking noise was provided by an exhaust fan within 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 were accomplished using a microcomputer located in a separate room.

### Procedure

*Phase 1 training.* The birds were magazine trained and then autoshaped to peck red and green fields. Training on 0-s delayed matching-to-sample began after each bird was pecking reliably. For the four birds assigned to the choice matching task, sessions consisted of 64 trials separated by an intertrial interval of 30 s. Each trial began with the illumination of the center key by the preparatory stimulus (a black dot on a white ground).

A single peck to the preparatory stimulus terminated it and resulted in immediate onset of the houselight. If the bird did not respond within 5 s, the preparatory stimulus was extinguished and the houselight was illuminated. The houselight duration was short (2 s) on a randomly selected half of the trials within each session, and on the remaining trials the houselight duration was long (8 s). Termination of the sample was followed immediately (0-s delay) by illumination of the two side keys, one with red light and the other with green light. The color that was correct for short and long samples was counterbalanced across birds, and spatial position of the correct comparison was balanced within sample duration (short and long). A single peck on either comparison terminated both comparison stimuli. If the correct comparison was pecked, a 3.5-s presentation of grain occurred as reinforcement. If the incorrect comparison was pecked, the trial terminated without reinforcement and 3.5 s was added to the intertrial interval.

For the four birds assigned to the successive matching task, sessions were identical to those employed in the choice matching task with the exception of the test portion of each trial. Specifically, rather than presenting two comparison stimuli for a choice, only a single test stimulus was presented on each trial. The test stimulus, either red or green, was presented on the right-most pecking key. The color that was positive for short and long samples was counterbalanced across birds. If the test stimulus was positive, the first response to occur 5 s or longer after illumination of the test stimulus produced 3.5 s of access to grain as reinforcement. If the test stimulus was negative, it was terminated after 5 s and 3.5 s was added to the intertrial interval. The test stimulus was equally often positive and negative within each sample duration. Responses to positive and negative test stimuli were recorded, with the response to positive test stimuli which procured reinforcement being excluded. In all other aspects, sessions of successive matching training were identical with those of choice matching training. Each of the eight birds received 56 sessions of training.

*Phase 1 testing.* Each bird received eight sessions of delay testing in which a randomly selected eight of the trials involved a 5-s delay and another randomly selected eight of the trials involved a 10-s delay (the remaining 48 trials within each session involved a 0-s delay as in training). Trials involving a 5- or 10-s delay were identical to 0-s delay trials except that a 5- or 10-s interval separated termination of the houselight sample and onset of the comparison stimuli (in the choice task) or onset of the test stimulus (in the successive task). Half of the trials at each delay involved a short sample (2 s of houselight illumination) and half involved a long sample (8 s of houselight illumination). For birds in the choice task, position of the correct comparison was equally often left and right within each of the four combinations of sample duration and delay. For birds in the successive task, the test stimulus was equally often positive

and negative within each of the four combinations of sample duration and delay.

Interpolated between sessions of delay testing were baseline sessions identical with those employed during training. For birds assigned to the choice task, a single baseline session intervened between each session of delay testing. For birds assigned to the successive task, additional baseline sessions were necessary because accuracy at the 0-s delay was disrupted by delay testing. The following numbers of baseline sessions preceded each of testing sessions 2 through 8: 6, 9, 3, 4, 5, 3, 3.

After the eighth session of delay testing, each bird received four sessions of baseline training followed by a single session of no-sample testing. The no-sample session was identical with the training sessions of phase 1 with the exception that on 16 of the 64 trials a sample was not presented. On no-sample trials, termination of the preparatory stimulus was followed immediately by the presentation of comparison stimuli (in the matching task) or onset of the test stimulus (in the successive task). A random 8 of the 16 no-sample trials were arbitrarily designated as "short trials" and the remaining 8 as "long trials." The reinforcement contingencies on "short trials" were identical with those on short-sample trials, and the reinforcement contingencies on "long trials" were identical with those on long-sample trials.

*Phase 2 training.* Immediately following the single session of no-sample testing in phase 1, the birds assigned to the choice task were transferred to the successive task and the birds assigned to the successive task were transferred to the choice task. Sessions of successive matching training and sessions of choice matching training were identical with those of phase 1 training. The transfer was arranged such that the reinforcement contingencies were consistent across tasks for each bird. That is, for birds transferred to the choice task the former positive test stimulus on short-sample trials became the correct comparison on short-sample trials, and the former positive test stimulus on long-sample trials became the correct comparison on long-sample trials. Similarly, for birds transferred to the successive task the former correct comparison on short-sample trials became the positive test stimulus on short-sample trials, and the former correct comparison on long-sample trials became the positive test stimulus on long-sample trials. The four birds which were transferred from the successive task to the choice task received eight sessions of training on choice matching. The four birds which were transferred from the choice task to the successive task received 68 sessions of successive matching training.

*Phase 2 testing.* Phase 2 delay testing sessions were identical with those of phase 1 delay testing. For birds tested in the choice task, a single baseline session intervened between each session of delay testing. For birds assigned to the successive task, additional baseline sessions were

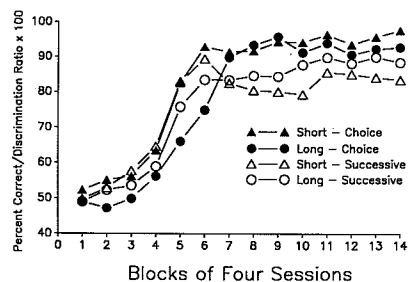


FIG. 2. Accuracy of matching to short and long samples in each group as a function of blocks of four sessions during Phase 1 training in Experiment 2. The dependent measure is the percentage correct in the choice task and discrimination ratio  $\times 100$  in the successive task.

necessary because accuracy at the 0-s delay was disrupted by delay testing. The following numbers of baseline sessions preceded each of testing sessions 2 through 8: 2, 3, 2, 3, 2, 3, 2.

After the eighth session of delay testing, each bird received four sessions of baseline training followed by a single session of no-sample testing. The session of no-sample testing was identical with the no-sample testing session conducted in phase 1 testing.

### Results

**Phase 1 training.** Acquisition of matching across blocks of four sessions is shown in Fig. 2. Accuracy on short-sample and long-sample trials is shown separately for each group. The acquisition functions were similarly S-shaped and accuracy increased more rapidly on short- than on long-sample trials in the two tasks. At a qualitative level, therefore, acquisition of choice and successive matching to duration samples proceeded similarly. At a quantitative level, some between-task differences in acquisition are apparent. For example, asymptotic accuracy levels were somewhat higher for birds trained in the choice task than for birds trained in the successive task. It should be noted that quantitative differences need to be viewed with caution because the dependent measure is different in choice (percentage correct) and successive (discrimination ratio) matching. Interest in the present paper is focused not on quantitative differences between choice and successive matching, but rather on whether forgetting would be manifest in qualitatively different ways in the two procedures. Specifically, the question of interest was whether forgetting would be manifest as an enhanced tendency to respond in accord with the contingencies of short-sample trials in the choice procedure and as an unbiased deterioration in accuracy in the successive procedure. The use of nonidentical dependent measures in the two tasks does not render this question empirically intractable.

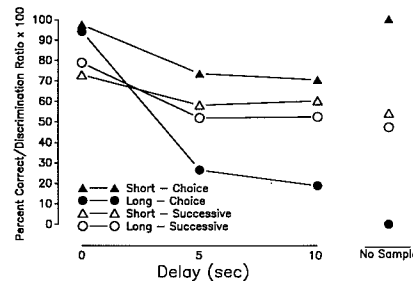


FIG. 3. Accuracy of matching to short and long samples in each group as a function of delay during phase 1 testing in Experiment 2. Performance on no-sample trials is shown in the right-most portion of the figure.

**Phase 1 testing.** The results of phase 1 delay and no-sample testing are shown in Fig. 3. Accuracy is shown separately on short- and long-sample trials in each task. Birds tested in the choice task (filled symbols) demonstrated a strong choose-short effect at the 5- and 10-s delays. Collapsed across sample duration, birds tested in the choice task responded to the comparison stimulus associated with the short sample on 51.7, 73.5, and 75.8% of the trials at delays of 0, 5, and 10 s, respectively. A Delay  $\times$  Sample Duration ANOVA revealed significant main effects of delay,  $F(2, 6) = 222.35$ , and sample duration,  $F(1, 3) = 20.67$ . The reliability of the choose-short effect was confirmed by the significant Delay  $\times$  Sample Duration interaction,  $F(2, 6) = 9.34$ .

Birds tested in the successive task (open symbols), on the other hand, did not display a marked respond-short tendency at the longer delays. Rather, accuracy decreased at approximately equivalent rates on both short- and long-sample trials as delay increased. A Delay  $\times$  Sample Duration ANOVA revealed a significant main effect of delay,  $F(2, 6) = 67.07$ . Neither the main effect of sample duration,  $F(1, 3) = 4.34$ , nor the Delay  $\times$  Sample Duration interaction,  $F(2, 6) = 3.05$ , was significant.

On no-sample trials, shown in the right portion of the figure, the birds tested in the choice task (filled symbols) chose the comparison associated with the short sample on each trial. On the other hand, birds tested in the successive task (open symbols) responded to all test stimuli at a high rate, resulting in discrimination ratios approximating .50.

**Phase 2 training.** Acquisition of choice matching for birds transferred from the successive task to the choice task is shown in the upper portion of Fig. 4. There was considerable positive transfer from the successive to the choice task; accuracy was 78.1% correct on the first session of choice matching and was asymptotic by the third training session.

Acquisition of successive matching for birds transferred from the choice task to the successive task is shown in the lower portion of Fig. 4. Notice

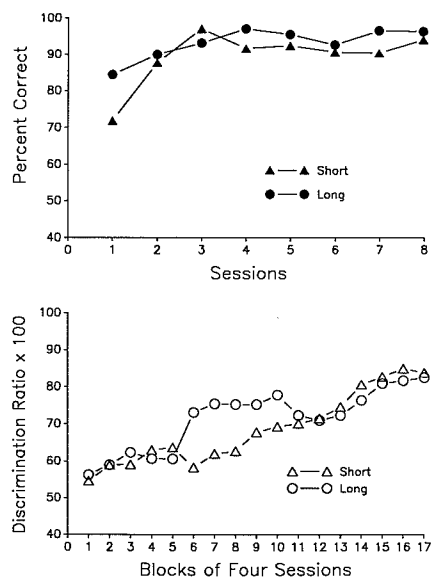


FIG. 4. Accuracy of matching to short and long samples in each group during phase 2 training in Experiment 2. The top portion shows accuracy in the choice task as a function of training sessions for animals transferred from the successive task to the choice task. The bottom portion shows accuracy in the successive task as a function of blocks of four training sessions for animals transferred from the choice task to the successive task.

here that accuracy is plotted across blocks of four sessions, rather than across individual sessions as in the upper portion of the figure. There was little evidence of positive transfer from the choice to the successive task. The discrimination ratio on the first session (not shown in the figure) was .512, and accuracy increased only slowly across blocks of training sessions. Comparing these acquisition functions with those of naive birds trained on precisely the same task (open-symbol curves in Fig. 2) reveals that initial training on the choice task tended to retard acquisition of successive matching.

**Phase 2 testing.** The results of phase 2 testing are shown in Fig. 5. The data from phase 1 testing are also shown in the figure to facilitate comparison. Data from animals tested in the successive task in phase 1 and in the choice task in phase 2 are shown in the upper portion of the figure. Data from animals tested in the choice task in phase 1 and in the successive task in phase 2 are shown in the lower portion of the figure.

Examination of the filled-symbol curves shown in the upper portion of the figure reveals that in birds originally trained and tested in the successive task, increasing delay length in a choice task did not produce a choose-short effect. Instead, accuracy tended to decline approximately equiva-

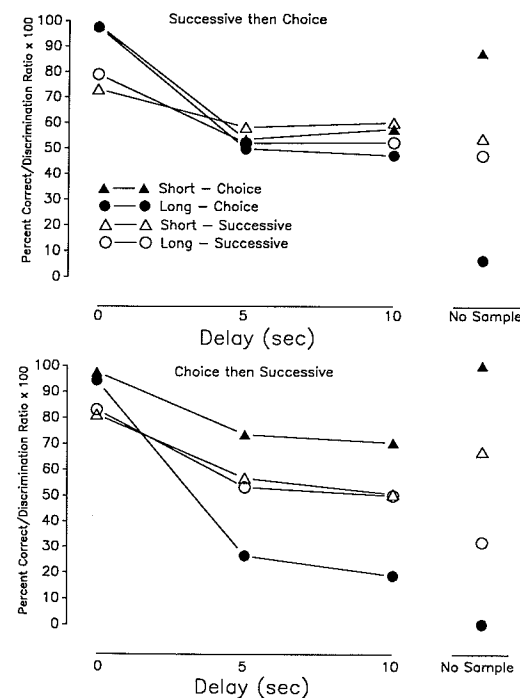


FIG. 5. Accuracy of matching to short and long samples as a function of delay in the choice and successive tasks in each group during testing in phase 1 and phase 2 in Experiment 2. The top portion shows accuracy for subjects trained initially in the successive task and the bottom portion shows accuracy for subjects trained initially in the choice task. Performance on no-sample trials is shown in the right-most portion of the figure.

lently on short- and long-sample trials as delay increased. A Delay  $\times$  Sample Duration ANOVA revealed a significant main effect of delay,  $F(2, 6) = 148.30$ . Neither the main effect of sample duration nor the Delay  $\times$  Sample Duration interaction was significant (both  $F_s < 1$ ).

Examination of the open-symbol curves shown in the lower portion of the figure reveals that in birds originally trained and tested in the choice task, increasing delay length in a successive task did not produce a respond-short effect. Instead, accuracy declined at an equivalent rate on short- and long-sample trials. A Delay  $\times$  Sample Duration ANOVA revealed a significant main effect of delay,  $F(2, 6) = 139.62$ . Neither the main effect of sample duration,  $F < 1$ , nor the Sample Duration  $\times$  Delay interaction,  $F(2, 6) = 2.84$ , was significant.

On no-sample trials, shown in the right portion of the figure, birds tested in the choice procedure in phase 2 (upper portion, filled symbols) chose the comparison associated with the short sample on 90.6% of the



trials. Birds tested in the successive task in phase 2 (lower portion, open symbols) also demonstrated a respond-short tendency on no-sample trials.

### Discussion

Phase 1 of the present experiment was conducted to provide a within-experiment evaluation of the role of assessment task in determining whether pigeons respond in accord with the contingencies of short-sample trials at longer delay intervals. Consistent with the results of several experiments in which a choice matching task has been employed (e.g., Spetch & Wilkie, 1982, 1983), naive birds which were trained and subsequently tested in a choice procedure demonstrated a choose-short effect at delays longer than those employed in training. Consistent with the results of our first experiment, in which a successive matching task was employed, naive birds which were trained and subsequently tested in a successive task did not demonstrate a respond-short effect at delays longer than those employed in training. Moreover, birds tested in the choice procedure responded in accord with the contingencies of short-sample trials during no-sample testing, whereas those tested in the successive procedure did not.

The results of the first phase in the present experiment are consistent with the conclusion reached on the basis of comparing the results of our first experiment with other published experiments. Specifically, pigeons tend to respond in accord with the contingencies of short-sample trials at longer delays when accuracy is assessed in a choice matching task, but not when accuracy is assessed in a successive matching task. Also consistent with this conclusion are the results from subjects tested first in the choice procedure and tested subsequently in the successive procedure. When tested in the choice procedure, these birds responded in accord with the contingencies of short-sample trials at longer delays. In contrast, when tested in the successive procedure, accuracy declined at an equivalent rate on short- and long-sample trials. The results from subjects tested initially in the successive task and tested subsequently in the choice task suggest a caveat to the conclusion that the nature of the assessment task is the critical determinant of whether or not pigeons respond in accord with the contingencies of short-sample trials at delays longer than those employed in training. In particular, these subjects did not demonstrate a choose-short effect at longer delays in the choice task. Rather, accuracy declined similarly on short- and long-sample trials as delay increased, a pattern identical with that shown earlier when these animals were tested in the successive task. Given the results from delay testing, the fact that these birds responded in accord with the contingencies of short-sample trials during no-sample testing in the choice task is surprising. It should be noted, however, that in Experiment 1, both groups displayed a respond-short tendency on no-sample trials but did not do so during delay testing.

This result was also obtained during testing in the successive task in phase 2 of the present experiment. Thus, it is unlikely that the tendency to respond in accord with the contingencies of short-sample trials on delay trials and on no-sample trials are related causally.

Finally, it should be noted that the transfer data are instructive with regard to the results of the within-subject comparison of the effects of delay testing in the two tasks. Subjects trained initially in the choice task did not demonstrate positive transfer when trained in the successive task, suggesting that in these subjects accurate performance in the two tasks was mediated by different timing and/or memorial processes. On the other hand, subjects trained initially in the successive task demonstrated substantial positive transfer when trained in the choice task, suggesting that in these subjects accurate performance in the two tasks was mediated by the same or similar timing and memorial processes. If so, it is not surprising that the latter subjects, unlike the former, showed similar effects of increasing delay in the two tasks.

### GENERAL DISCUSSION

The effect of delay on pigeons' memory for event duration appears to be quite different in the successive matching-to-sample task, and the choice matching-to-sample task. When naive pigeons are trained and tested in the choice task, they show a marked tendency to respond in accord with the contingencies for short samples at delays longer than the training value. In contrast, pigeons that are trained and tested in the successive task show a reduction in discrimination accuracy at long test delays but this is not accompanied by a consistent tendency to respond in accord with the contingencies for short samples.

This difference in the effect of delays is surprising because, on the surface at least, the two tasks seem similar in terms of memory requirements and it is generally assumed that discriminative responding in successive tasks is logically related to frequency correct in choice tasks (e.g., Roitblat & Weisman, 1986). Moreover, there is no evidence from studies of memory for other types of sample events (e.g., colors or forms) that would lead one to expect different functional relationships to emerge in these two assessment tasks. To the contrary, many similarities between the effects of various manipulations in these tasks have been reported (e.g., Nelson & Wasserman, 1978).

There is, however, some previous evidence to suggest that discrimination of temporal events is influenced by procedural variables. Chatlosh and Wasserman (1987) examined pigeons' delayed temporal discriminations in a choice procedure that included two different types of trials. On "stimulus trials" the duration of the sample determined which of two choice stimuli (slanted vs. horizontal lines) would be correct (regardless of their location). On "position trials," the sample duration determined

whether the right or left choice key was correct (regardless of which stimulus it contained). The pigeons learned the position task faster than the stimulus task, and for two of the four birds, manipulation of the delay had a different effect in the two tasks: The delay disrupted accuracy in the stimulus task but not in the position task. Chatlosh and Wasserman suggested that the same processes might not mediate performance in these two tasks. They argued further that procedural considerations have important implications for theories of timing and cautioned that:

Failure to scrutinize procedural details when attempting to consolidate findings into a cohesive theory of temporal discrimination may result in misconceptions about animal timing processes, while preoccupation with a single procedure will most probably result in conclusions that do not generalize across other experimental paradigms (p. 308).

The present results seem to reinforce this cautionary view. It appears that the processes that mediate pigeons' memory for temporal events in choice tasks are not necessarily the same as those that mediate their memory for temporal events in successive tasks. This is suggested both by the different effects of delay in the two tasks, and by the asymmetrical transfer effects that occurred when pigeons were switched from the choice to the successive task, or from the successive to the choice task in Experiment 2. Pigeons showed immediate positive transfer when switched from successive to choice, and the effects of delay on their performance in the choice task mirrored that shown previously in the successive task. This suggests that the timing and/or memory strategies that were acquired in the successive task led to successful performance in the choice task and therefore continued to operate within the choice task. In contrast, no immediate transfer was shown for birds switched from the choice to the successive task; indeed the birds appeared to learn more slowly as a result of their previous exposure to the choice task. Moreover, the effects of delay on their performance in the successive task did not mirror that shown previously in the choice task. This suggests that the timing and/or memory strategies acquired by naive pigeons within the choice task were unsuccessful in generating accurate performance in the successive task and had to be abandoned in favor of other strategies.

The different effects of delay in the two tasks and the between-task transfer effects might reflect different coding strategies which naive pigeons employ in the two tasks. Specifically, naive pigeons might code samples of different durations retrospectively in terms of perceived duration in the choice task. At the time of testing, remembered duration controls choice between the comparison stimuli. In the successive task, in contrast, naive pigeons might code samples of different durations prospectively in terms of an instruction to respond and/or not respond to a

particular test stimulus. At the time of testing, response rate is controlled by the content of the remembered code.

The notion that duration samples are coded retrospectively, combined with the view that remembered duration becomes subjectively shorter as time in the absence of that event increases (see Spetch & Wilkie, 1983), correctly anticipates that naive pigeons will demonstrate a choose-short tendency at longer delays in the choice task. The notion that duration samples are coded prospectively correctly anticipates that naive subjects will not demonstrate a respond-short tendency in the successive task because responding in the absence of a remembered code should be non-systematic with respect to event duration.

The present view maintains that the transfer results reflect the extent to which accurate performance in the two tasks can be mediated by coding processes acquired in the alternative task. In particular, a prospective coding strategy of the form "respond to stimulus A" and/or "do not respond to stimulus B" acquired in the successive task is sufficient to generate accurate performance in the choice task. Hence, animals transferred from the successive task to the choice task should demonstrate substantial positive transfer. However, because these animals are employing a prospective coding strategy in the choice task, they should not demonstrate a choose-short tendency during delay testing in the choice task. On the other hand, a retrospective coding strategy of the form "if remembered duration is X choose comparison A instead of comparison B" is not sufficient to generate accurate performance in the successive task. Hence, animals transferred from the choice task to the successive task should demonstrate little positive transfer. Moreover, to the extent that these animals abandon the retrospective strategy and adopt a prospective one in acquiring the successive task, subsequent delay testing should fail to reveal a respond-short tendency.

Thus, the view that naive pigeons employ a retrospective coding strategy in the choice task and a prospective coding strategy in the successive task, combined with a consideration of the extent to which each strategy would be expected to be immediately applicable to the alternative procedure, allows one to provide a plausible account of our results from both transfer and delay testing. Moreover, the present account also has the virtue of leading to several testable predictions. For example, the present account anticipates that any procedure which induces prospective coding in the choice procedure should eliminate both the choose-short effect during delay testing and the temporal summation effect during sample repetition testing (see Spetch & Sinha, 1989 for a demonstration of the temporal summation effect). To test this prediction we are conducting delay and temporal summation tests within a "many-to-one" choice procedure (two samples are mapped on to each comparison stimulus) which should encourage prospective coding. A second prediction derived from the present

account is that temporal summation should not occur in the successive procedure because the samples are coded prospectively. We are also currently testing this prediction.

Finally, we have given some consideration to factors which might induce pigeons to evaluate sample durations retrospectively in a choice task, but to use a prospective strategy in a successive task. One such speculation is that the choice task might tend to emphasize comparative evaluations whereas the successive task might emphasize independent evaluations. To elaborate, because of the choice component, the choice task emphasizes "oppositional" or "versus" decisions: choose comparison A versus comparison B. For samples that are perceived as lying along a continuum (e.g., different durations or different numbers), the choice task may additionally emphasize an oppositional evaluation of the samples (e.g., long versus short) and thereby encourage remembering of the samples (retrospective coding). The successive procedure, on the other hand, involves a go/no go assessment, which might emphasize instructional aspects of the task (e.g., given sample X, respond to test stimulus A and do not respond to test stimulus B; given sample Y, respond to test stimulus B and do not respond to test stimulus A). Under such conditions, subjects may treat the two different durations as comprising two separate tasks or problems, rather than as components of a single matching task. Thus, the nature of the assessment technique employed in the successive task may particularly discourage retrospective coding and/or encourage prospective coding.

A second speculation concerning possible reasons why the two tasks might encourage different coding strategies focuses on differences between the tasks in exposure to the test stimuli compared to exposure to the sample stimuli. In the choice task with duration samples, the pigeons typically spend considerably more time in the sample period than they do in the choice period: exposure time to the sample is determined by sample duration and averages 5 or 6 s. In contrast, exposure to the comparison stimuli can be very brief because the comparisons terminate as soon as the first response is made. This differential exposure time may enhance the salience of the samples relative to the comparison stimuli, and thereby encourage retention of the sample duration (retrospective coding). In the successive task, on the other hand, the time spent in the presence of the test stimuli is approximately the same as the average time spent in the sample period. Moreover, reinforcement is provided following a minimum of 5 s of exposure time to the positive test stimulus, and by this time the sample is temporally quite remote. This could place much greater emphasis on the test stimuli, and thereby encourage a prospective coding strategy.

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Received September 22, 1989

Revised April 23, 1990