

Pigeons' Memory for Event Duration in Choice and Successive Matching-to-Sample Tasks

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Pigeons were trained to discriminate between short (2 s) and long (10 s) house-light samples within successive or choice delayed matching-to-sample tasks, and then were given four types of tests. During one type of test, the delay interval between the sample and test period was manipulated within sessions. Consistent with earlier findings, pigeons in the choice task displayed a reliable choose-short tendency at longer delays, whereas those in the successive task failed to show an analogous respond-short tendency. A second type of test entailed multiple sample presentations: the short and long samples were preceded by short or long pre-samples. Pigeons in both the choice and successive tasks showed a temporal-summation effect rather than a sample-consistency effect. In a third type of test, the intertrial interval was manipulated within sessions. Pigeons in both tasks showed a respond-long bias when the intertrial interval preceding the trial was shortened. In a final test, pigeons received no-sample tests, and tests with a 40-s sample. Pigeons in both groups showed a strong tendency to respond short on no-sample tests, and to respond long following a 40-s sample. It appears that timing processes are similar in the two tasks, but that memorial processes differ.

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Studies of short-term memory in pigeons have often used either a choice matching-to-sample task or a successive matching-to-sample task. In the typical version of both of these tasks, one of two sample events is presented at the start of a trial and then memory for some property of that event is assessed following a retention interval. The two tasks differ only in how this memory is assessed. In the choice task, two comparison stimuli are presented, one of which is correct following one sample event and the other of which is correct following the other sample event. The percentage of correct choices provides an index of sample discrimination and

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memory. In the successive task, only one of two comparison stimuli is presented on each trial. One comparison is positive following one sample and negative following the other sample, and the contingencies are reversed for the other comparison. In the successive task, differential rates of responding on positive and negative trials provide the index of sample discrimination and memory.

On the surface, these tasks seem to entail similar memory requirements. That is, the pigeon must in some way retain information about which sample was presented over the delay interval in order to choose the correct comparison stimulus in the choice task, or to differentiate between positive and negative stimuli in the successive task. Moreover, studies using these procedures to investigate pigeons' memory for color or line orientation samples have not provided any indication that different memory processes underlie performance in these two procedures (see, Nelson & Wasserman, 1978; Roitblat & Weisman, 1986).

Apparently, however, these two procedures do not provide equivalent indices of memory processes when the attribute to be remembered is the duration of the sample event. We recently compared performance in choice and successive tasks using different durations of the same event as the samples and found that manipulation of the delay interval produced qualitatively different results in the two procedures (Grant & Spetch, 1991). In the choice task, pigeons showed an asymmetrical decline in accuracy: Accuracy decreased to a much greater extent on long-sample trials than on short-sample trials when the delay was increased. This effect is referred to as the "choose-short effect" (Spetch & Wilkie, 1982), and has been reported in several other studies using the choice task (Kraemer, Mazmanian, & Roberts, 1985; Spetch, 1987; Spetch & Rusak, 1989; 1992a; Spetch & Wilkie, 1983). In contrast, within the successive task we observed a decline in accuracy as a function of delay that was similar on both short- and long-sample trials. Thus, an analogous "respond-short" tendency did not emerge within the successive task. Wasserman, DeLong, and Larew (1984) also found no evidence of a respond-short tendency in pigeons' memory for duration within a successive matching procedure.

Other differences between the two procedures also appeared when we transferred the pigeons from one procedure to the other (Grant & Spetch, 1991). Birds that had been trained on the successive procedure immediately responded accurately when tested on the choice task. However, birds that had been trained on the choice task did not respond accurately when transferred to the successive task. Instead they required a large number of sessions to learn the successive task. Apparently, the strategy being used to produce accurate performance within the successive task was also effective within the choice procedure, but the strategy being used within the choice task was not effective within the successive procedure. Consistent with this assumption was our finding that birds trained first on

the successive task and then transferred to the choice task responded differently to delay manipulations than did birds trained only on the choice task. That is, the birds with prior training on the successive task failed to display a choose-short effect when the delay interval was manipulated within the choice task, suggesting that their performance on the choice task continued to be governed by a strategy learned during training on the successive task.

On the basis of these results, we concluded that the processes being used in the successive task were not the same as those normally used in the choice task, and we speculated that what might differ is the type of memory code used to retain the temporal information (Grant & Spetch, 1991). Specifically, we endorsed the proposal (Spetch & Sinha, 1989; Wilkie & Willson, 1990) that in the choice task, pigeons retain an analogical representation of the sample duration over the delay, and assess the duration retrospectively at the time of choice. In contrast, we proposed that in the successive task, pigeons do not retain the duration information in its analogical form, but instead transform it into prospective codes, such as "peck red" and "peck green." These prospective codes would then be retained over the delay and would guide responding to the comparison stimuli.

The present study was designed to extend our earlier work by further characterizing performance in choice and successive tasks in which samples differ in duration. In addition to delay manipulation tests, pigeons in the present study were exposed to three other types of tests. One was the multiple-sample test used by Spetch and Sinha (1989) and Wilkie and Willson (1990) to provide evidence for analogical retention of the temporal sample information. In these tests, the short or long target samples are preceded on test trials by short or long presamples. Two qualitatively different sets of results are possible. First, the birds might show a sample-consistency effect, characterized by high accuracy on test trials in which the presample is the same duration as the sample (both short or both long) and low accuracy on trials in which the durations of the presample and the sample differ (short-long or long-short). Such an effect would be in accord with results from choice matching-to-sample tasks using non-temporal samples (e.g., Grant, 1982a,b; Grant & Roberts, 1973). Spetch and Sinha (1989) suggested that a sample-consistency effect would be expected if the pigeons retained a nonanalogical code of the sample durations because accuracy should be high whenever the two sample presentations activate the same code (e.g., if both the presample and the sample activate the code "peck red") but low if the presample activates a code that conflicts with the code activated by the target sample (e.g., if the presample activates the code "peck green" but the target sample activates the code "peck red").

The second possible result is a temporal-summation effect, in which

presentation of a presample would result in high accuracy on trials in which the target sample was long and low accuracy on trials in which the target sample was short. This pattern would be expected if pigeons coded duration analogically and summed across the duration of the presample and the target sample; this summation would lead to an overestimation of the sample duration, which should lead to accurate performance when the correct response is to the long-associated comparison and inaccurate performance when the correct response is to the short-associated comparison.

Spetch and Sinha (1989) and Wilkie and Willson (1990) reported temporal-summation effects rather than sample-consistency effects within the choice task and they interpreted this as evidence for analogical retention of the temporal information. Based on our proposal that the successive task induces pigeons to retain the temporal information in a nonanalogical form, we expected that a sample-consistency effect rather than a temporal-summation effect would be observed in the successive procedure.

The second type of test used in the present study was a within-session manipulation of the intertrial interval (ITI). Spetch and Rusak (1989; 1992a) have reported that varying the duration of the preceding ITI leads to systematic errors within choice matching-to-sample tasks using duration samples. Most notably, when the ITI preceding the trial was shorter than normal, pigeons displayed a choose-long tendency. An opposite choose-short tendency emerged when the ITI was longer than normal; however, this latter effect appeared reliably only when the ITI was manipulated in the context of a lengthy (e.g., 10-s) delay (Spetch & Rusak, 1989). Because of the qualitative similarity between manipulations of the delay and ITI, and because the effects of manipulating one of these temporal variables depends in part on the value of the other, Spetch and Rusak (1989, 1992a,b) have suggested that delay and ITI effects might reflect a common mechanism. Specifically, they proposed that pigeons might attend to the duration of the sample relative to the surrounding temporal background composed of the ITI and the delay. Manipulating either component of the surrounding temporal background would change the relative duration of the sample.

Given that delay manipulations have qualitatively different effects within choice and successive tasks in which duration is the relevant sample dimension, it was of interest to determine whether ITI manipulations would also have qualitatively different effects within these two procedures. If the difference in delay performance exclusively reflects the use of different types of memory codes within the two tasks, then manipulation of the ITI might not produce different effects within the two tasks. Specifically, because the ITI precedes the sample presentation, it may operate to alter the subjective duration of the sample prior to the formation of

a memory code. Hence its effects may be independent of the memory code. On the other hand, qualitatively different effects of ITI in the two tasks would be expected if either (a) the different delay effects reflect the operation of different timing processes in addition to, or instead of, the use of different memory codes, or (b) the ITI does not affect timing of the sample duration but instead modulates only the remembered sample duration.

Our final test phase was included to facilitate interpretation of some of the results we obtained from the delay tests and the multiple sample tests. Some of the test trials in this phase were no-sample tests, in which the sample event was omitted. Previous no-sample tests within choice and successive tasks have produced ambiguous results. In the choice task, a strong bias toward making short choices emerges reliably on no-sample test trials (e.g., Spetch & Wilkie, 1983; Grant & Spetch, 1991). In the successive task, a reliable tendency to peck more to the test stimulus that is positive for short samples has emerged in some groups of subjects but not in others (Grant & Spetch, 1991). Thus, it was important to determine whether a reliable respond-short effect on no-sample trials would be displayed by the successive group in the present experiment. The occurrence of a reliable respond-short effect in the successive task would suggest that a failure to observe a respond-short effect after long delays was not due to an insensitivity of the task to variables that lead to biased responding. On other test trials in this phase, the sample was extended to 40 s, which is the longest combined value of the multiple sample presentations. Determining how pigeons respond to an extra long sample was important for assessing the results of the multiple sample tests. These no-sample and 40-s sample tests may also be viewed as a temporal generalization test in which values shorter and longer than the training durations are presented. If the difference between the choice and successive tasks is in the type of memory code used, but not in timing processes, these tests should yield similar results in the two tasks.

METHOD

Subjects

The subjects were 12 naive Silver King pigeons, between 6 months and 1 year of age. Six birds were assigned to the choice procedure and six to the successive procedure. One pigeon died during the course of initial training on the successive procedure, leaving 5 birds in the successive group. All birds were maintained at approximately 85% of their free-feeding weights by mixed grain obtained during the experimental sessions, and by supplemental feedings in the home cages. The pigeons were housed in large individual cages with water and grit freely available. The colony was maintained on a 12 h dark/light cycle.

Apparatus

The pigeons were tested in standard operant chambers that contained either two or three horizontally aligned pecking keys. A grain feeder was centered below the pecking keys, and food presentations were accompanied by illumination of a lamp within the feeder. A houselight was centered above the pecking keys, and the light was directed toward the ceiling. Stimulus projectors mounted behind the keys were used to illuminate the keys with uniform fields of red or green light. A fan provided ventilation and background masking noise. A microcomputer located in an adjacent room was used to control the experimental contingencies and record responses.

Procedure

Preliminary training. All pigeons first received 1 to 3 sessions of magazine training followed by a few sessions with a modified autoshaping procedure to establish pecking to the two side keys when periodically illuminated with red or green light. In this procedure, food was presented immediately if the pigeon pecked at an illuminated key; otherwise the key illumination terminated after 8 s and then food was presented.

Baseline training. Baseline training sessions for birds in both groups consisted of 48 trials separated by a 45-s ITI. In the choice procedure, trials began with the presentation of the houselight for either 2 s ("short" sample) or 10 s ("long" sample). Immediately (i.e., 0-s delay) following termination of the sample, the two side pecking keys were illuminated, one with red light and one with green light. The spatial position of the colors was always balanced within sample duration (short and long), and the color that was correct for short samples was counterbalanced across the six birds. A single peck to the correct comparison terminated both comparisons and produced 4 s access to the grain feeder. A single peck to the incorrect comparison terminated both comparisons and led directly to the ITI.

The successive procedure was identical in all aspects except for the conditions in effect during the comparison stimulus period. In this procedure only one comparison stimulus was presented on any trial: either red or green illumination of the left pecking key. For three birds, red was positive following short samples and negative following long samples whereas green was negative following short samples and positive following long samples; the opposite contingencies were used for the remaining birds. Positive and negative trials were presented equally often in each session and were always balanced within sample duration. On positive trials, the first response to occur 5 s after illumination of the comparison stimulus terminated the stimulus and produced 4 s access to the grain feeder. On negative trials, the comparison stimulus terminated after 5 s and food was not presented.

All birds were trained on their assigned task for a minimum of 20 sessions. Accuracy of responding was assessed for each bird after the 20th, 40th, and 50th session. Birds in the choice group were moved to testing if their overall accuracy, averaged over the preceding five sessions, was 80% correct or greater. Birds in the successive group were moved to testing if their overall discrimination ratio, averaged over the preceding five sessions, was .80 or higher. In the choice group, five birds received 20 training sessions, and one bird received 40 training sessions. In the successive group, two birds received 20 training sessions, one bird received 40 training sessions, and two birds received 50 training sessions.

Following baseline training, all birds were exposed to six test phases in the order presented below. Each bird received a minimum of two baseline sessions following each test phase. If accuracy was below 70% correct in the choice task or below a discrimination ratio of .70 in the successive task on either of these baseline sessions, up to eight additional baseline sessions were given before the next test phase was initiated.

Test phase 1: delay manipulation. This phase consisted of eight sessions during which longer delays were presented on some of the trials. Twenty-four trials in each session contained the 0-s baseline delay, 12 trials contained a 5-s delay, and 12 trials contained a 10-s delay. The short and long samples occurred equally often at each delay, and the order of the various trial types was determined randomly within each block of 24 trials.

Test phase 2: double sample tests. During each of the eight sessions in this test phase, half of 48 trials were double-sample test trials in which presentation of the sample was preceded by a presample presentation of the houselight for either a short (2 s) or a long (10 s) duration. The reinforcement contingencies were always appropriate to the target sample (the last one presented before the test). Presample presentation was separated from presentation of the target sample by a 5-s interstimulus interval (ISI). The four possible combinations of presample and sample durations (short-short; long-long; short-long; long-short) occurred equally often in each session. The remaining trials were baseline trials in which only the short or long sample was presented. The order in which baseline and test trials were presented was determined randomly within each block of 24 trials.

Test phase 3: ITI manipulations. During each of the eight sessions in this test phase, 24 trials were preceded by the 45-s baseline ITI, 12 trials were preceded by a 5-s ITI, and 12 trials were preceded by an 85-s ITI. Each ITI duration occurred equally often before short and long samples, with order of presentation determined randomly for each block of 24 trials.

Test phase 4: multiple sample tests. This phase consisted of 16 test sessions in which three short or three long presample presentations of the houselight preceded the short and long target samples on 12 test trials.

On 12 other test trials, one short or one long presample presentation of the houselight preceded the short and long target samples. The reinforcement contingencies on test trials were always appropriate to the target sample. The remaining 24 trials were baseline trials on which only the short or long target sample was presented. The order of baseline and test trials was determined randomly for each block of 24 trials. The ISI between the three presamples, and between the last presample and the target sample, was 1 s during eight of the sessions, and 3 s during the remaining eight sessions. The ISIs alternated every fourth session so that each ISI was in effect twice for 4 consecutive sessions each time. Half of the birds in the choice task and two of the birds in the successive task started with the 1-s ISI. This phase was conducted to provide a more powerful assessment of temporal-summation versus sample-consistency effects. Presenting three presamples, and shortening the ISI between successive presample presentations and between the presample and target sample, should strengthen the impact of either temporal-summation effects or sample-consistency effects on responding.

Test phase 5: delay tests. This phase consisted of eight test sessions that were identical to those given in Test phase 1.

Test phase 6: no-sample and 40-s sample tests. During the four sessions in this phase, 24 of the trials were baseline trials, 12 were no-sample test trials in which the sample was omitted, and 12 test trials began with the presentation of a 40-s houselight as the sample. The order of baseline and test trials was determined randomly for each block of 24 trials. The reinforcement contingencies in effect for short samples occurred on a randomly selected half of the no-sample and 40-s trials and the contingencies in effect for long samples occurred on the remaining test trials.

Statistical analyses. Accuracy in the choice task was assessed in terms of the percentage of correct choices made on trials initiated by a short sample and on trials initiated by a long sample. In the successive task, discrimination ratios (responses to S+ / responses to S+ plus responses to S-) were computed for trials initiated by a short sample and for trials initiated by a long sample. For some of the tests, the proportion of long responses was also computed. In the choice task, this measure represents the proportion of trials in which the comparison appropriate to the long sample was chosen on a particular type of trial. In the successive task, this measure is based on responses to the S+ for long samples divided by responses to both the S+ and the S- for long samples for a particular type of trial. Because the performance measures are not identical for the two tasks, the data from each task were analyzed with separate repeated-measure ANOVAs. Significant effects were further analyzed with Newman-Keuls multiple comparisons. The criterion for rejection of the null hypothesis was set at .05 for all statistical tests.

RESULTS

Delay Tests (Test Phases 1 and 5)

The top graphs in Fig. 1 show the results of the first phase of delay testing, and the bottom graphs show the results of the replication of the delay tests in phase 5. The results of the first test series clearly showed that birds in the choice task (left graph) show a choose-short effect when the delay is lengthened, whereas birds in the successive task (right graph) do not show an analogous respond-short effect, and instead show a more symmetrical decline in discrimination accuracy as a function of delay. During the second delay test series (bottom graphs), the decline in accuracy over delays shown by birds in the successive task was slightly asymmetrical, but still differed substantially from that shown by birds in the choice task.

For Test phase 1, two-way ANOVAs with delay and sample duration as the factors revealed a significant main effect of delay for both groups

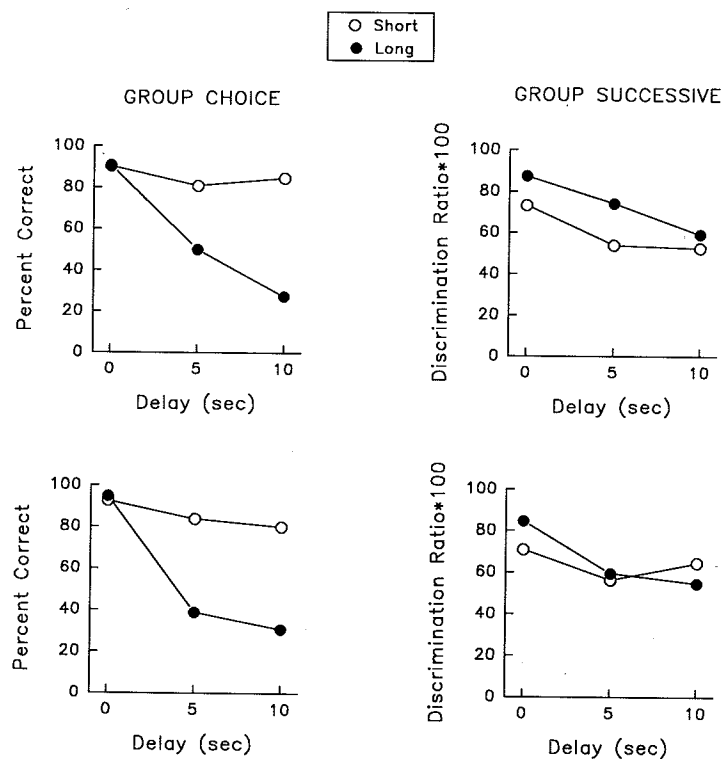


FIG. 1. Accuracy on short-sample and long-sample trials as a function of delay interval for both groups of birds during the initial series of delay tests in phase 1 (top) and the replication of the delay tests in phase 5 (bottom).

(choice: $F(2, 10) = 40.34$; successive: $F(2, 8) = 25.82$), but only the choice group showed a significant main effect of sample duration (choice: $F(1, 5) = 11.00$; successive $F(1, 4) = 3.49$). Most importantly, the interaction between delay and sample duration was significant for the choice group, ($F(2, 10) = 14.03$), but not for the successive group ($F(2, 8) = 1.46$). Subsequent multiple comparisons on the data from the choice group confirmed that the interaction reflected a typical choose-short effect: Accuracy was significantly higher on short-sample trials than on long-sample trials at the 5-s delay and the 10-s delay, but not at the 0-s delay.

Similar ANOVAs on the data from Test phase 5 revealed that both groups showed a significant effect of delay (choice: $F(2, 10) = 182.26$, successive: $F(2, 8) = 23.31$), but that only the choice group displayed a significant effect of sample duration (choice: $F(1, 5) = 38.65$; successive: $F(1, 4) < 1$). Although the interaction between delay and sample duration was significant for both groups (choice: $F(2, 10) = 52.42$, successive: $F(2, 8) = 6.52$), subsequent multiple comparisons suggested that the source of the interaction differed between the two groups. Specifically, multiple comparisons for the choice group indicated that accuracy was significantly higher on short-sample trials than on long-sample trials at the 5-s delay and the 10-s delay, but not at the 0-s delay, thus confirming the development of a choose-short effect as delay is lengthened. In contrast, multiple comparisons for the successive group revealed that accuracy was significantly higher on long-sample trials than on short-sample trials at the 0-s delay, but that accuracy on short-sample and long-sample trials did not differ significantly at the two longer delays. Thus, the slightly asymmetrical decline in accuracy as a function of delay did not reflect the development of a reliable respond-short effect for the successive group.

Multiple Sample Tests (Test Phases 2 and 4)

The top graphs in Fig. 2 show accuracy from the double sample tests given in Test phase 2. Results for the choice group are shown in the left graph, and results for the successive group are shown in the right graph. In each graph, the first bar of each triplet shows accuracy on baseline trials in which only the short (S) or long (L) target sample was presented. The middle bar of each triplet shows accuracy on trials in which a pre-sample was presented that was consistent in duration with the target sample (S-S and L-L). The last bar of each triplet shows accuracy on trials in which the presample and target sample durations were inconsistent (L-S and S-L). For all pairs of axis labels, the first letter refers to the presample duration and the second letter refers to the sample duration. A sample-consistency effect would be indicated by high accuracy on the consistent trials (S-S and L-L), and low accuracy on the inconsistent trials (L-S and S-L), relative to baseline. A temporal-summation effect, on the other hand, would be indicated by an increase in the proportion

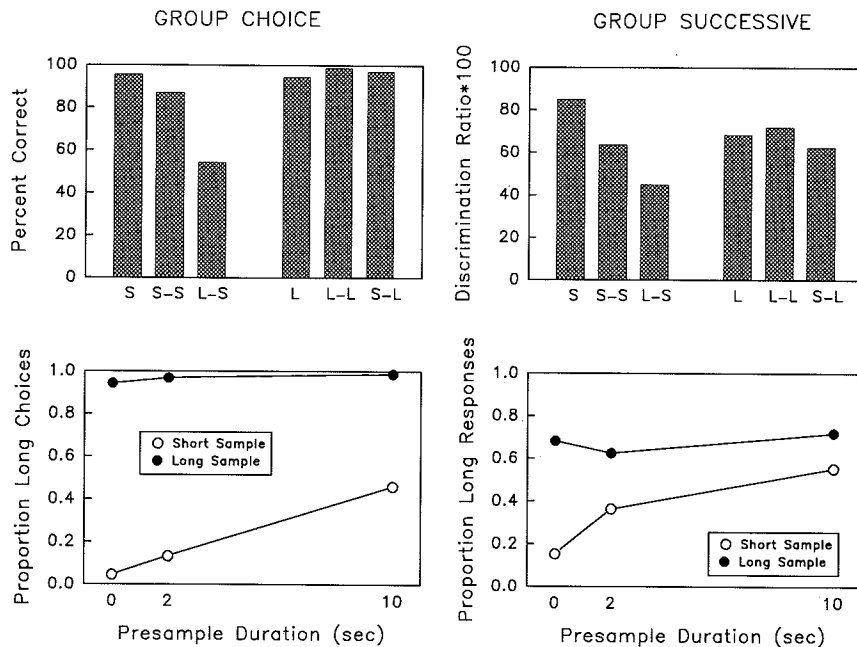


Fig. 2. Results of the double-sample tests (Test phase 2) for both groups of birds. The top graphs show accuracy on short (S) and long (L) baseline trials as well as accuracy on trials in which these target samples were preceded by a presample of the same duration (S-S and L-L) or by a presample that differed in duration from the target sample (L-S and S-L). The first letter of each x-axis label indicates whether the presample was short or long and the letter in the second position indicates whether the target sample was short or long. The bottom graphs show the results in terms of the proportion of long responses as a function of presample duration.

of long responses as a function of presample duration, which would enhance accuracy on long target-sample trials (S-L and L-L) and lower accuracy on short target-sample trials (S-S and L-S). Temporal-summation effects can be seen most clearly when the proportion of long responses on short and long target-sample trials is plotted as a function of presample duration, as shown in the bottom graphs of Fig. 2.

For choice birds, the overall pattern of results fits the predictions based on temporal summation better than those based on sample consistency. Specifically, the inconsistent S-L combination resulted in slightly higher accuracy than L alone, whereas the consistent S-S combination resulted in slightly lower accuracy than S alone. In addition, the proportion of long choices increased markedly on short target-sample trials, and slightly on long target-sample trials as a function of presample duration. For successive birds, the pattern was similar but not quite as clear. Accuracy was considerably lower on S-S trials than on S trials, but accuracy was

also slightly lower on S-L trials than on L trials. The proportion of long responses increased markedly on short-sample trials but did not change systematically on long-sample trials as a function of presample duration.

The effects of presample condition on the proportion of long responses were analyzed with separate one-way ANOVAs for the short and long target samples. For both groups, these ANOVAs revealed a significant main effect of presample duration for the short target sample (choice: $F(2, 10) = 22.89$; successive: $F(2, 8) = 19.44$) but not for the long target sample (choice: $F(2, 10) = 1.52$; successive: $F(2, 8) = 3.57$). Multiple comparisons on the short target-sample data revealed that for both groups, the proportion of long responses was significantly higher with a 10-s presample (L-S trials) than with a 2-s or 0-s presample (S-S and S trials). For the successive group, the proportion of long responses was also higher with a 2-s presample (S-S trials) than with no presample (S trials).

The multiple sample tests conducted in Test phase 4 provided a stronger test of the predictions based on sample consistency versus temporal summation, because three presamples were presented on some trials, and two shorter ISIs between the presample presentations and between the presample and target sample were tested. The results of these tests can be found in Figs. 3 and 4, with the accuracy scores shown in Fig. 3 and the proportion of long responses shown in Fig. 4 (the data points at presample durations of 6 s and 30 s are from the test trials with three short and three long presamples, respectively). For both choice and successive birds, the results of these tests provided more support for temporal-summation than for sample-consistency effects. In particular, three successive presentations of the short presample disrupted accuracy on short target-sample (3S-S) trials but not on long target-sample (3S-L) trials; the opposite result would be expected on the basis of sample consistency.

The effects of presample condition on the proportion of long responses were analyzed with separate one-way ANOVAs for each target sample at each ISI. Both groups showed a significant effect of presample duration in both ISI conditions when the target sample was short (1-s ISI, choice: $F(4, 20) = 38.61$; successive: $F(4, 16) = 29.83$; 3-s ISI, choice: $F(4, 20) = 8.39$; successive: $F(4, 16) = 14.16$). For the choice group, multiple comparisons revealed that the proportion of long responses was significantly higher on 3S-S, 1L-S, and 3L-S than on S trials at the 1-s ISI, but with the 3-s ISI, only the 1L-S and 3L-S trials differed significantly from the S trials. For the successive group, multiple comparisons revealed that in both ISI conditions, the proportion of long responses was significantly higher on each of the presample test types than on S trials.

When the target sample was long, the choice group showed significant effects of presample duration in both ISI conditions (1-s ISI: $F(4, 20) = 4.41$; 3-s ISI: $F(4, 20) = 3.14$), but the successive group did not show significant presample effects under either ISI condition (1-s ISI, $F(4, 16)$

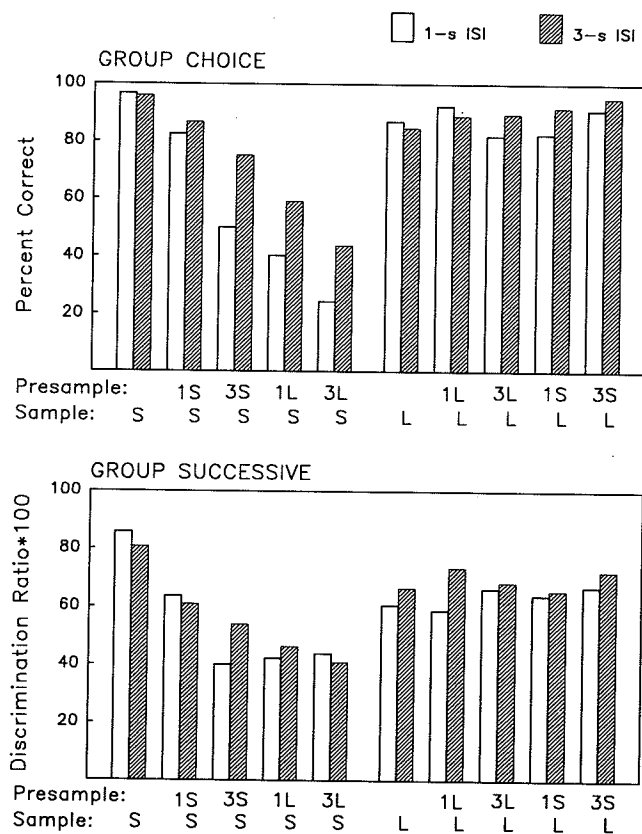


FIG. 3. Accuracy scores on each test trial type during the multiple sample tests (Test phase 3) for the choice and successive groups. Open bars are from tests with a 1-s ISI and filled bars are from tests with a 3-s ISI. For the x-axis labels, the numbers and letters in the top row refer to the presample condition and the letter in the bottom row refers to the target sample.

< 1; 3-s ISI, $F(4, 16) = 1.56$). Multiple comparisons for the choice group indicated that the proportion of long responses on L trials was not significantly different from that made on any of the test trials with a pre-sample in the 1-s ISI condition, but differed from the 3S-L trials in the 3-s ISI condition.

ITI Manipulation Tests

Figure 5 shows the results of Test phase 3 in which the duration of the ITI varied within sessions. Birds in both groups showed a decrease in accuracy on short-sample trials but not on long-sample trials when the ITI preceding the trial was shortened to 5 s.

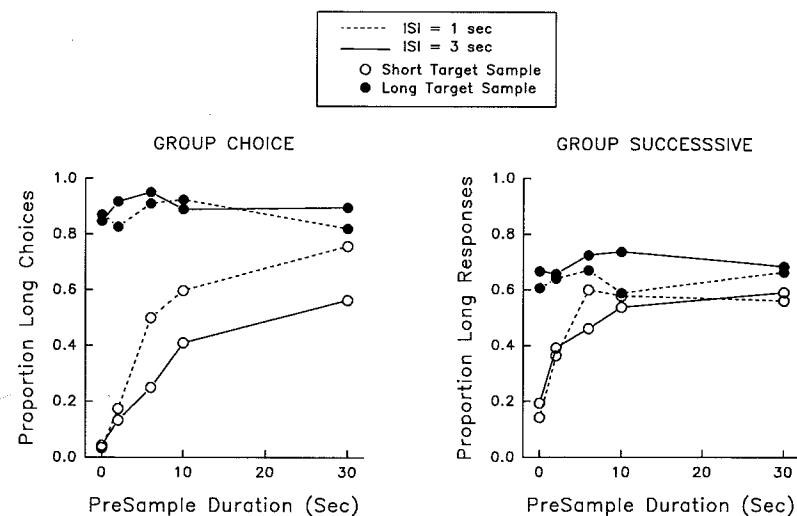


FIG. 4. Proportion of long responses as a function of presample duration with the 1-s ISI and the 3-s ISI during the multiple sample tests (Test phase 4) for the choice and successive groups. The data points at presample durations of 6 s and 30 s are from the tests with three successive short presamples and tests with three successive long presamples, respectively.

Two-way ANOVAs with the factors being ITI and sample duration revealed that both groups showed significant main effects of ITI (choice: $F(2, 10) = 11.10$, successive: $F(2, 8) = 26.03$). The main effect of sample duration was significant for the choice group ($F(1, 5) = 9.09$) but not for the successive group ($F(1, 4) = 1.01$). Most importantly, the interaction between ITI and sample duration was significant for both groups

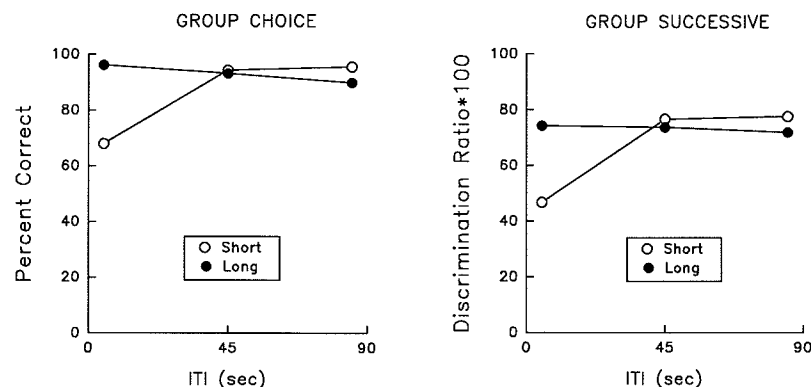


FIG. 5. Accuracy on short-sample and long-sample trials as a function of the ITI that preceded the trial for choice and successive groups during Test phase 3.

TABLE 1
Mean Proportion of Responses Appropriate to the Long Sample on No-Sample, Baseline (Short and Long), and 40-s Sample Trials

No sample	Short (2-s) sample	Long (10-s) sample	40-s sample
		Choice Group	
.202	.072	.935	.900
		Successive Group	
.223	.272	.776	.857

(choice: $F(2, 10) = 13.61$, successive: $F(2, 8) = 11.90$), and multiple comparisons confirmed that this was due to a respond-long effect at the shortest ITI for both groups. Specifically, both groups showed significantly higher accuracy on long-sample trials than on short-sample trials following a 5-s ITI, but showed no significant differences between accuracy on short-sample and long-sample trials following 45- or 85-s ITIs.

No-Sample and 40-s Sample Tests

Table 1 shows the mean proportion of responses appropriate to the long sample on no-sample and 40-s sample test trials, as well as on the short and long baseline trials from Test phase 6. In both groups, the proportion of long responses was low on no-sample and short-sample trials, and high on long-sample and 40-s sample trials. For both groups, ANOVAs confirmed that the proportion of long responses differed across the sample conditions (choice, $F(3, 15) = 145.30$; successive, $F(3, 12) = 23.92$), and multiple comparisons revealed that the proportion of long responses was significantly lower on no-sample and short-sample trials than on long-sample or 40-s sample trials. For the choice group, but not for the successive group, multiple comparisons also revealed a significant difference between the no-sample and short-sample trials. For neither group was there a significant difference between the proportion of long responses made on long-sample trials and 40-s sample trials.

DISCUSSION

It is clear from inspection of the figures and the table that the only manipulation to have qualitatively different effects in the choice and successive tasks was that of varying the delay (i.e., the retention interval). Despite some quantitative differences in accuracy levels within the two tasks, manipulations of the ITI, the sample duration, and presample presentations all had qualitatively similar effects within the two tasks. The difference in response to delay manipulations in the context of similar responses to manipulation of other variables suggests that the differences

between the two tasks is specific to the way in which temporal information is retained over a delay interval.

In addition to highlighting the specificity of the differential delay effects, the present results rule out one trivial interpretation of the failure to observe a respond-short effect within the successive procedure, namely that this task is just less sensitive than the choice task to variables that bias responding to one of the test stimuli. In this study, the proportion of long responses in the successive task was clearly sensitive to the effects of ITI and presample manipulations, and a bias toward the short test stimulus occurred on the no-sample trials. Thus, there is no reason to assume that a process operating during the delay which should induce a bias toward the short test stimulus would fail to be detected in the successive procedure.

The results of the multiple-sample tests warrant specific attention. At the time these tests were initiated, our assumption was that temporal-summation effects were indicative of the memory code: specifically that temporal summation would only occur if the samples were retained in a retrospective and analogical form, and that sample-consistency effects would occur instead if the temporal information was prospectively coded (Spetch & Sinha, 1989). However, the present data, together with other recent evidence (Grant & Spetch, submitted; Santi, Bridson, & Ducharme, 1991) suggest that this assumption may be erroneous. In the present study, the memory functions for the choice and successive groups were qualitatively different, suggesting that the temporal information was retained differently in the two tasks, and yet both groups showed evidence of temporal summation in response to the multiple sample tests. In other recent work, use of a many-to-one procedure, which is thought to induce prospective or common coding (both of which are nonanalogical forms of coding), has been found to eliminate the choose-short effect (Grant & Spetch, 1993; Santi *et al.*, 1991), but subjects in the many-to-one procedure continue to show temporal-summation effects rather than sample-consistency effects during multiple-sample tests (Grant & Spetch, submitted; Santi *et al.*, 1991). As recently proposed by Kraemer and Roper (1992), it appears that the tendency to sum across successively presented sample durations reflects some aspect of the timing system and is independent of the memory code normally used to retain the sample information until the test period. In the context of an internal clock framework (e.g., Church, 1984), one possibility is that a second sample presentation adds counts to the accumulator which still contains counts from the first sample and that a new memory code is then formed based on the total counts at the end of the second sample (Kraemer & Roper, 1992). In this model, either an analogical or a nonanalogical code would be updated whenever a new sample is presented, and so a temporal-summation effect would

be expected regardless of how the temporal information is retained over the delay interval.

The ITI manipulations also warrant discussion. Spetch and Rusak (1989; 1992a,b) have hypothesized that ITI variation might alter the perceived or remembered duration of the sample because of context effects; specifically that a given interval seems shorter in the context of a long background time than in the context of a short background time. This view implies relative temporal processing: that sample durations are judged at least partly on the basis of how long they last relative to the temporal context in which they occur. Spetch and Rusak suggested that the choose-short effect may also in part reflect context effects, because increases in the delay interval would increase the temporal background in which the sample occurs.

At first blush, the fact that birds in the successive task showed the typical ITI effect, but failed to show a respond-short effect, appears inconsistent with Spetch and Rusak's analysis. Notice, however, that in order for increases in the delay to affect remembered sample duration through a change in background time, the sample duration would need to be evaluated retrospectively at the time of choice (see Spetch & Rusak, 1992b). If birds in the successive task code the sample in a nonanalogical form prior to the delay, changes in the background time after the code is formed would not be expected to alter the code in any systematic way. On the other hand, since the ITI determines the background that precedes the sample, it should influence the perceived duration of the sample, and hence the code that is formed. Therefore, the present finding that birds in the successive task demonstrated a respond-long effect when the ITI was shortened but failed to display a respond-short effect when the delay was lengthened is consistent with Spetch and Rusak's relative-duration hypothesis if, as argued here, pigeons code duration nonanalogically in the successive task.

The no-sample and 40-s sample tests corroborate our interpretations of the delay tests and multiple sample tests, respectively. First, it is important to note that subjects in the two tasks responded in a highly similar fashion to the no-sample tests, despite the fact that they responded very differently following long delays after a sample presentation. This dissociation strains the suggestion (Kraemer *et al.*, 1985) that the choose-short effect reflects forgetting of the sample information, such that pigeons respond after a long delay as though no sample had been presented. From this view, it is not clear why birds in the successive group would show a substantial drop in accuracy with long delays, but fail to show a respond-short bias, given that they do show such a bias when no sample is presented.

The results of the tests in which the sample was extended to 40 s support our conclusions that the pattern of results observed during multiple sample tests was in accord with temporal summation. One potentially problematic

aspect of those results, for both groups of subjects, was that the presample presentations consistently produced a significant increase in the proportion of long choices only when the target sample was short. Although ceiling effects may account for some instances of failure to obtain a statistically significant increase in the respond-long tendency as a function of presample duration on long target-sample trials, this cannot explain all such instances, particularly for the successive birds. The results of the tests with a 40-s sample (which is equivalent to the combined duration of three long presamples and a long target sample) suggest that a statistically significant increase in long responses will not necessarily occur when the sample is increased beyond the training value. This result implies that the summation of duration across the separate presample and long target-sample presentations would not necessarily produce a substantial increase in the tendency to respond long beyond that present with the long target-sample alone.

Taken together, the present results suggest that the processes underlying the timing and assessment of the sample durations are similar in the choice and successive tasks, but that the memory code used to retain the temporal information differs. Thus, the present results support our earlier suggestion that pigeons retain sample information in a different form in successive and choice tasks (Grant & Spetch, 1991). Further research employing different kinds of manipulations will be needed to identify the form of the memory code used in the successive procedure.

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Effects of the Number of Trials per Session on Autoshaping in Rats

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Acquisition in Pavlovian conditioning is usually faster the fewer the number of trials per session (TPS). Three experiments studied this TPS effect in autoshaping with rats. In Experiment 1, a group receiving 40 1-trial sessions acquired faster than a group receiving 2 20-trial sessions, and faster than an unpaired control. In Experiment 2, nonreinforced preexposure to the lever produced more lever-pressing when it involved a single TPS than when it involved 20 TPS. Additionally, subsequent acquisition was positively correlated with the amount of responding during preexposure, but only significantly so in the group trained with 20 TPS. In Experiment 3, acquisition with 1 TPS was faster with a long-delay procedure than with a trace procedure. The implications of the TPS effect for an understanding of the impact of multiple-trials training procedures on acquisition is discussed in relation to the role of habituation, sensitization, and temporal contiguity in conditioning. © 1993 Academic Press, Inc.

Conditioning situations in which there is a similar degree of temporal contiguity between the conditioned stimulus (CS) and the unconditioned stimulus (US) may produce different levels of performance depending on the distribution in time of these CS-US pairings. A familiar phenomenon that occurs in a wide variety of situations is the *trial-spacing effect*—the direct relationship between the acquisition of conditioned responding to a CS and the length of the intertrial interval (Domjan, 1980; McAllister, McAllister, Weldin, & Cohen, 1974; Mitchell, 1973; Salafia, Mis, Terry, Bartosiak, & Daston, 1973; Spence & Norris, 1950; Terrace, Gibbon, Farrell, & Baldock, 1975). Contemporary theories of learning and performance point to the value of the context as the source of the trial-spacing effect (Gibbon & Balsam, 1981; Miller & Schachtman, 1985; Pearce & Hall, 1980; Rescorla & Wagner, 1972). According to these theories, relatively massed trial conditions generate substantial contextual

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