LEARNING AND MOTIVATION **27,** 179–199 (1996)
ARTICLE NO. 0011

Procedural Determinants of Coding Processes in Pigeons' Memory for Duration

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Pigeon's retention functions for duration samples differ qualitatively in choice and successive delayed-matching-to-sample tasks. This research tested procedures designed to be hybrids of these tasks. In Experiment 1, adding a fixed-interval component to the test phase of the choice procedure did not eliminate the ''respond-short'' effect that is characteristic of retention functions for duration in the choice task. A respond-short effect was not present after the birds were subsequently trained in the successive task. In Experiment 2, a choice component was added to the successive task by providing an option stimulus that could be selected to obtain reinforcement on S-trials that followed either short or long samples. Pigeons showed a respond-short effect under this successive-option procedure but did not show a respond-short effect after training with the option stimulus removed from the successive procedure. Thus, the different retention functions obtained in choice versus successive tasks do not appear to reflect differences in the temporal aspect of the test stimulus schedule or the successive versus simultaneous viewing of the test stimuli. Instead, a respond-short effect emerges when subjects make a choice response based on sample duration, but not when they make a go/no-go response based on sample duration.

The processes that underlie pigeons' memory for a recently presented stimulus have been the subject of considerable recent investigation. Much of this research has employed either a choice matching-to-sample or a successive matching-to-sample task, both of which are widely used assessment tools for investigations of working memory in pigeons. In both tasks, a sample event is presented at the start of the trial and then memory for that event is assessed following a delay interval. In the choice task, this assessment involves presenting subjects with a choice between two test stimuli, one of which is designated as correct for the sample that was presented and one that is designated as

This research was supported by NSERC operating grants held by each of the first and second authors (OPG0038861 to M.L.S.; OGP0443 to D.S.G.). Reprint requests should be addressed to Marcia L. Spetch or Douglas S. Grant, Department of Psychology, University of Alberta, Edmonton, Alberta T6G 2E9, Canada. E-mail: mspetch@psych.ualberta.ca or dgrant@psych.ualberta.ca.

0023-9690/96 $18.00

incorrect. Choice accuracy after various delays provides the index of subjects' memory for the sample. In the successive task, a single test stimulus is presented following the delay. On some trials the test stimulus is correct for the sample presented and on other trials it is incorrect. Relative rates of responding to the correct and incorrect test stimuli after various delays provide the index of memory.

Although these two tasks are very similar, recent evidence from studies employing temporal samples has indicated that they do not reflect equivalent memory processes (Grant & Spetch, 1991; Spetch & Grant, 1993). In the choice task, when different durations of the same event serve as the samples, pigeons show an asymmetrical decline in accuracy with increasing delays. Specifically, accuracy declines to a much greater extent on trials initiated by a long sample than on trials initiated by a short sample, an effect labeled as the ''choose-short effect'' by Spetch and Wilkie (1982). This effect is reliably obtained when naive pigeons are tested in the typical choice matching-to-sample task involving two duration samples and two choice stimuli (see Grant, 1993, and Spetch & Rusak, 1992b, for reviews). In contrast, increases in the delay interval within successive matching-to-sample tasks lead to symmetrical declines in accuracy on trials initiated by short and long samples (Grant & Spetch, 1991; Spetch & Grant, 1993; Wasserman, DeLong, & Larew, 1984). Thus, in the successive task, pigeons do not show a ''respond-short'' tendency that would be analogous to the choose-short effect displayed in the choice task. The assessment procedure used therefore appears to be an important determinant of the memory functions obtained with duration samples (see also Chatlosh & Wasserman, 1987). Grant and Spetch (1991) proposed that this difference reflected the use of different coding processes within the two tasks. Specifically, they concurred with earlier suggestions (e.g., Spetch & Wilkie, 1983) that pigeons employ a retrospective, analogical code to remember sample duration in the choice task, but suggested that in a successive task, pigeons may use a nonanalogical, prospective code.

Additional comparisons of performance in choice and successive tasks provided support for the assumption that the locus of the differential performance is in memory processes, rather than in timing processes (Spetch & Grant, 1993). Specifically, manipulation of the duration of the sample, the number of sample presentations, and the duration of the preceding intertrial interval all had comparable effects within the two tasks. The differential effect of delay interval, together with the similar effects of these other manipulations, suggested that the difference between the two tasks is specific to the way in which temporal information is retained.

Also consistent with the suggestion that pigeons employ different coding processes in the two tasks is the observation that transfer of accurate performance does not occur bidirectionally (Grant & Spetch, 1991). Birds trained first on the successive task immediately responded accurately when transferred to the choice task, and then failed to display a choose-short effect on the choice task. In contrast, birds trained first on the choice task did not immediately respond accurately when transferred to the successive task and instead required substantial retraining. Furthermore, they failed to show a respond-short effect on the successive task despite having previously shown a choose-short effect on the choice task. It appears that the coding processes that mediate accurate responding on the successive task can be applied effectively in the choice task and will continue to be used by birds that are transferred from the successive to the choice task. However, the processes that normally mediate accurate responding in the choice task do not appear to be effective in the successive task, and hence a strategy appropriate to the successive task must be learned.

Although the evidence is clear in supporting the notion that memory processes differ in the two tasks, it is not clear why this difference occurs. The lower density of reinforcement in the successive procedure does not seem to be an important factor, because reducing the density of reinforcement in a choice task does not eliminate the choose-short effect (Fetterman, 1995; Grant & Spetch, 1994). The delay between the sample and reinforcement in the successive task also does not seem to be critical, because a choose-short effect still occurs in the choice task when subjects are trained from the outset with a 5-s delay between the sample and choice opportunity (Spetch & Rusak, 1992a). Beyond these factors, however, it is not clear which of the differences between the choice and successive tasks might be important for producing the different memory functions. The present research was designed to isolate the critical distinguishing feature(s) of the choice and successive tasks that induces different coding processes. Accordingly, the present studies investigated pigeons' memory for sample duration within tasks that were hybrids of the choice and successive tasks.

EXPERIMENT 1a

One factor that differs between the choice and the successive task is the time spent in the presence of the test stimuli. In the choice task, this time is typically very brief because the test stimuli last only until the pigeon makes a choice response. In the successive task, on the other hand, the test stimulus lasts for the duration of a fixed interval (FI) or fixed time (FT) period, typically 5 s. There are two potential consequences of this difference. First, the ratio of time spent in the presence of the samples to time spent in the presence of the test stimuli may affect the relative salience of the sample and test stimuli. This might influence the type of code that is adopted. Specifically, larger ratios of sample time to test stimulus time may emphasize attributes of the sample which might encourage retrospective coding. Smaller ratios of sample time to test time may emphasize attributes of the test component of the trial, which might encourage prospective coding. If this were the case, then increasing the time spent in the presence of the test stimuli in a choice task should lead to prospective coding and hence eliminate the choose-short effect.

The second potential consequence of the difference in the test schedules is that use of FI and FT schedules in the successive task may encourage timing of the test stimuli. This timing might interfere with an analogical code of the sample duration. Consequently, analogical retention may be abandoned and replaced by a prospective strategy. If so, then adding an FI component to the choice task should result in a shift to a prospective strategy and elimination of the choose-short effect.

In the present experiment, two procedures that add an FI component to the test phase of the choice task were designed. In one procedure (FI-Chosen), the test phase began with presentation of both the correct and the incorrect test stimuli. A peck to one test stimulus terminated the other and initiated a 5-s FI schedule if the correct test stimulus had been pecked or a 5-s FT schedule if the incorrect test stimulus had been pecked. Food was presented upon completion of the FI schedule, whereas the trial ended without reinforcement upon completion of the FT schedule.

In the second task (FI-Both), both the correct and the incorrect test stimuli were presented for a 5-s FI. The 5-s interval was initiated as soon as the test stimuli were presented and was terminated by the first response made to either stimulus after the 5-s period had elapsed. During the 5-s interval, responses on either key were recorded but had no consequence. Food was presented only if the terminal peck was to the correct stimulus.

Both of these tasks provide a ratio of sample to test stimulus exposure that is similar to that in the successive task. In addition, they include a fixed time period that might encourage timing of the test stimuli. If either of these features underlies the absence of a respond-short effect within the successive task, then birds should fail to show the effect in either of these hybrid tasks.

Method

Subjects

Eight naive Silver King pigeons (*Columba livia*), each between 6 and 12 months old, served as subjects for this experiment. Birds were reduced to 85% of their free-feeding weight and were maintained at this approximate level throughout the experiment with presentations of mixed grain during sessions and supplementary feedings after sessions, if necessary. Between sessions, subjects were individually housed in wire mesh cages in a colony room and given continuous access to water and grit. The colony was maintained on a 12-h light/dark cycle (lights on at 7:00 AM).

Apparatus

Procedures were conducted in standard operant pigeon chambers, each containing either two or three horizontally aligned pecking keys (2.5 cm in diameter). Each key required a force greater than or equal to approximately 0.25 N. Stimulus projectors mounted behind each key were used to transilluminate the keys with uniform fields of red, green, or yellow. A grain feeder was centered below the pecking keys, and a lamp within the feeder was used to illuminate food presentations. A houselight was centered horizontally above the pecking keys and a lamp shield was affixed to direct the light toward the chamber ceiling. A fan provided ventilation and background masking noise. Presentation of stimulus events and the recording of responses was accomplished with a microcomputer located in an adjoining room.

Procedure

Preliminary training. All pigeons received sessions of magazine training until reliable approach and feeding from the food hopper was observed. Next, birds were given several sessions of autoshaping to establish pecking to green and red fields on each of the side keys.

Baseline (0-s delay) training. On the day following preliminary training, birds were randomly assigned to groups FI-Chosen and FI-Both, with the restriction that each group be composed of four birds. For both groups, trials began with the onset of the houselight for either 2 s (‘‘short’’ sample) or 10 s (‘‘long’’ sample). Immediately following sample termination (i.e., 0-s delay), red and green test stimuli were presented on the side keys. Each color was presented equally often on the left and right, counterbalanced within sample type. For two birds in each group, red was correct following short samples and green was correct following long samples. The contingencies were reversed for the remaining two birds in each group. For both groups, trials were separated by a 45-s intertrial interval (ITI) during which the chamber was dark.

For subjects in the FI-Chosen group, the initial keypeck recorded to either of the two test stimuli terminated the alternate test stimulus. If the peck was to the correct test stimulus, a 5-s FI schedule was initiated; the first peck recorded after the 5-s interval elapsed terminated the test stimulus and produced a 4-s presentation of the food hopper, followed by the ITI. If the initial peck was to the incorrect test stimulus, the test stimulus terminated without reinforcement after 5 s and was followed directly by onset of the ITI.

For subjects in the FI-Both group, the choice stage of a trial consisted of a 5-s FI schedule during which both test stimuli were present and all keypecks were recorded. The keypeck that concluded the FI schedule terminated both stimuli. If this terminal keypeck was to the correct test stimulus, a 4-s hopper presentation preceded onset of the ITI. If the terminal keypeck was to the incorrect test stimulus, reinforcement was omitted and the ITI began immediately.

For subjects in both groups, each session consisted of 48 trials. Baseline training concluded when a bird had completed at least five four-session blocks of baseline training and when mean accuracy for the initial choice pecks was at least 80% correct for two consecutive blocks. If a bird had not met this criterion by session 60 (block 15), the criterion was relaxed by removing the requirement that the two blocks with an 80% accuracy level must be consecutive.

Delay test 1 (0-, 5-, 10-s delays). This phase consisted of eight consecutive 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, between termination of the sample and onset of the test stimuli. Sample duration and spatial location of the correct test stimulus was balanced within each delay, and the order of the various trial types was determined randomly within each block of 24 trials. At all delays, contingencies were identical to those of a subject's baseline training. At the end of this phase, birds were returned to baseline training until the mean accuracy of initial choice pecks was at least 80% correct for two consecutive sessions.

Delay test 2 (0-, 10-, 20-s delays). This phase was identical to the first delay test except that test sessions included 0-, 10-, and 20-s delay intervals (24 trials at 0-s delay and 12 trials each at 10- and 20-s delays).

Accuracy Measures

The primary dependent measure was one that could be calculated for both groups, namely the percentage of initial choice pecks to the correct test stimulus. Two additional measures of accuracy were also obtained for group FI-Both: (1) the percentage of terminal pecks to the correct test stimulus (note that the terminal peck determined trial outcome) and (2) a discrimination ratio computed by dividing the total number of pecks to the correct test stimulus by the total number of pecks to both test stimuli. All measures were computed separately for short-sample and long-sample trials during delay testing. For all statistical analyses, the criterion for rejection of the null hypothesis was $p < .05$.

Results

Acquisition

Birds in Group FI-Both met the accuracy criteria in a mean of 21 sessions (range = 20 to 24), and birds in Group FI-Chosen required a mean of 41 sessions (range = 20 to 72). This difference was not significant, $t(6) = 1.81$.

Delay Tests

The percentages of correct initial choices made by each group on short- and long-sample trials during the two series of delay tests are shown in Fig. 1. Birds in both groups showed asymmetrical retention functions, with accuracy declining more on long-sample trials than on short-sample trials as a function of delay. The statistical significance of this respond-short effect was reflected by the interaction term of a two-factor (Delay and Sample Duration) analysis of variance (ANOVA) for each group during each delay test. For Group FI-

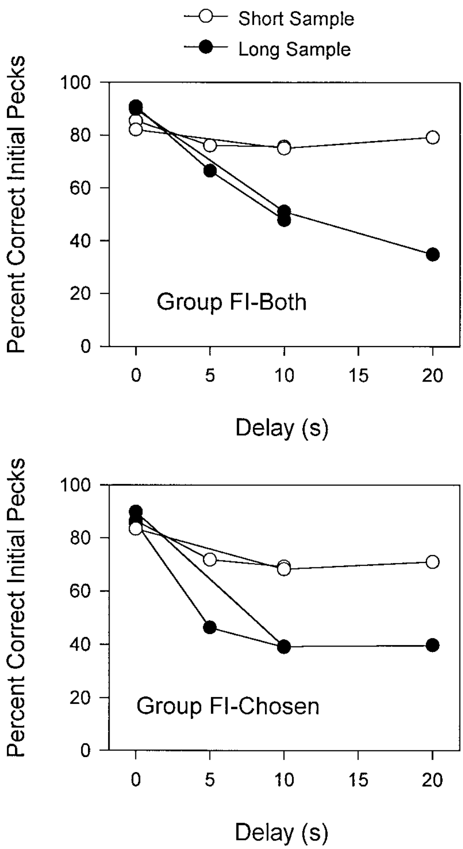

FIG. 1. Initial peck accuracy as a function of delay on short-sample and long-sample trials for birds in Group FI-Both (fixed interval on both test stimuli) and Group FI-Chosen (fixed interval on the chosen test stimulus) in Experiment 1a.

Both, the Delay by Sample Duration interaction was significant during both delay tests (Delay Test 1, $F(2,6) = 8.03$; Delay Test 2, $F(2,6) = 12.98$). Subsequent multiple comparisons (Tukey's HSD test) revealed that during Delay Test 1, accuracy was significantly higher on short-sample trials than on long-sample trials at the 10-s delay but did not differ at either the 0-s or the 5-s delays. During Delay Test 2, accuracy was significantly higher on short-sample trials than on long-sample trials at the 10- and 20-s delays but did not differ at the 0-s delay. For Group FI-Chosen, the Delay by Sample Duration interaction was not significant in Delay Test 1, $F(2,6) = 1.99$, but was significant in Delay Test 2, $F(2,6) = 6.77$. Tukey's comparisons on the Delay Test 2 results revealed that accuracy was significantly higher on short-sample trials than on long-sample trials at the 10- and 20-s delays but did not differ at the 0-s delay.

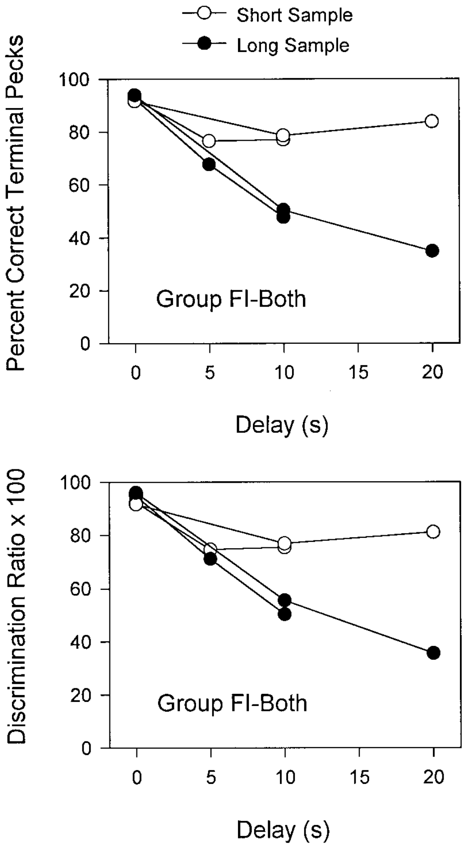

FIG. 2. Terminal peck accuracy (top) and total peck accuracy (bottom) as a function of delay on short-sample and long-sample trials for birds in Group FI-Both (fixed interval on both test stimuli) in Experiment 1a.

The terminal peck accuracy and discrimination ratio measures for Group FI-Both also showed a respond-short effect during both delay tests (see Fig. 2). ANOVAs revealed significant Delay by Sample Duration interactions during both delay tests for terminal peck accuracy (Delay Test 1, $F(2,6) = 9.10$; Delay Test 2, $F(2,6) = 11.43$) and for discrimination ratio (Delay Test 1, $F(2,6) = 13.04$; Delay Test 2, $F(2,6) = 10.41$). Tukey's HSD test revealed that, for both measures, accuracy was higher on short-sample trials than on long-sample trials at the 10- delay in Delay Test 1 and at the 10- and 20-s delays in Delay Test 2.

Discussion

Adding a temporal component to the choice period clearly did not eliminate the respond-short effect. The asymmetrical retention functions observed with the two hybrid tasks are qualitatively similar to those obtained in the standard matching-to-sample choice task and differ from the symmetrical retention functions typically obtained in the successive task (Grant & Spetch, 1991; Spetch & Grant, 1993). Thus, the coding processes induced by the successive procedure apparently do not reflect either the extended time period in the presence of the test stimuli relative to that in the presence of the sample stimuli (Grant & Spetch, 1991) or the use of a test schedule that might reactivate the timing system. The present results also indicate that the respond-short effect is not restricted to tasks in which only a single choice peck is made during each trial.

EXPERIMENT 1b

Grant and Spetch (1991) found that pigeons that were trained on the choice task did not immediately respond accurately when transferred to the successive task and required an extensive relearning period to achieve accurate performance. On subsequent delay tests in the successive task, the birds showed symmetrical retention functions, rather than the asymmetrical functions that they had shown in the choice task. In the present experiment, the birds that had been trained on the hybrid tasks of Experiment 1a were similarly transferred to and tested on the successive task.

Method

Subjects and Apparatus

Immediately after completion of Experiment 1a, the eight subjects participated in this experiment. The apparatus was identical to that of Experiment 1a.

Procedure

Transfer was arranged so as to maintain the same contingency between sample duration and the correct (i.e., positive) test stimulus as experienced by each bird in Experiment 1a.

Baseline training. The baseline successive matching-to-sample procedure was identical to that of the two procedures used in Experiment 1a in all aspects except those pertaining to the test period. During the test period, only a single test stimulus (red or green light) was presented on the left key on each trial. On positive trials, the test stimulus stayed on until an FI 5-s schedule was satisfied, and was followed by 4-s access to food. On negative trials, the stimulus remained on for 5 s and then terminated without food. An equal number of positive and negative trials were presented for each sample type, and the order of trial types varied randomly within blocks of 24 trials. Baseline training concluded once a bird had received a minimum of five four-session blocks and mean discrimination ratios were .8 or greater for two consecutive blocks.

Delay testing. Each bird received two series of delay testing, one with delays of 0, 5, and 10 s and one with delays of 0, 10, and 20 s. Other than the use of a successive procedure, these delay testing phases were conducted in a fashion identical to those described in Experiment 1a.

Accuracy Measure

The measure of accuracy was a discrimination ratio, computed by dividing the total number of pecks to positive test stimuli by the total number of pecks to both positive and negative test stimuli. This ratio was computed separately for short-sample trials and long-sample trials during each session of delay testing.

Results

Acquisition

Figure 3 shows mean discrimination ratios ($\times$100) for birds transferred from the FI-Both or FI-Chosen task during the initial five blocks of four sessions on the successive task. The inset shows discrimination ratios during the four sessions of the first block. Moderate levels of transfer are apparent in that mean discrimination ratios were above .5 even during the first session. For birds that were previously in Group FI-Both, accuracy was significantly above chance level (.5) according to one-tailed t tests during the first session, $t(3) = 5.23$, and during all blocks of four sessions ($t(3) = 7.70$, 9.89, 9.54, 10.42, and 21.87 for blocks 1 to 5, respectively). For birds previously in Group FI-Chosen, accuracy was not significantly above chance during the first session, $t(3) = 1.07$, but was significantly above chance during all blocks of four sessions ($t(3) = 2.90$, 2.96, 3.02, 4.09, and 6.39 for blocks 1 to 5, respectively).

Delay Tests

Figure 4 shows mean discrimination ratios ($\times$100) on short-sample and long-sample trials as a function of delay during the two series of delay tests. These functions show little evidence of a respond-short tendency at the longer delays. Although a slight asymmetry in the functions for short- and long-sample trials is apparent, it appears to be due to a respond-long tendency at the shorter delays rather than a respond-short tendency at the longer delays.

For birds that were previously in Group FI-Both, ANOVAs on the discrimination ratios failed to reveal a significant interaction between Delay and Sample Duration during either the first delay test, $F(2,6) = 2.46$, or the second delay test, $F(2,6) = 3.35$.

For birds that were previously in Group FI-Chosen, the Delay by Sample Duration interaction was significant during the first delay test, $F(2,6) = 8.61$. However, subsequent multiple comparisons (Tukey's HSD test) revealed that accuracy was significantly higher on long-sample trials than

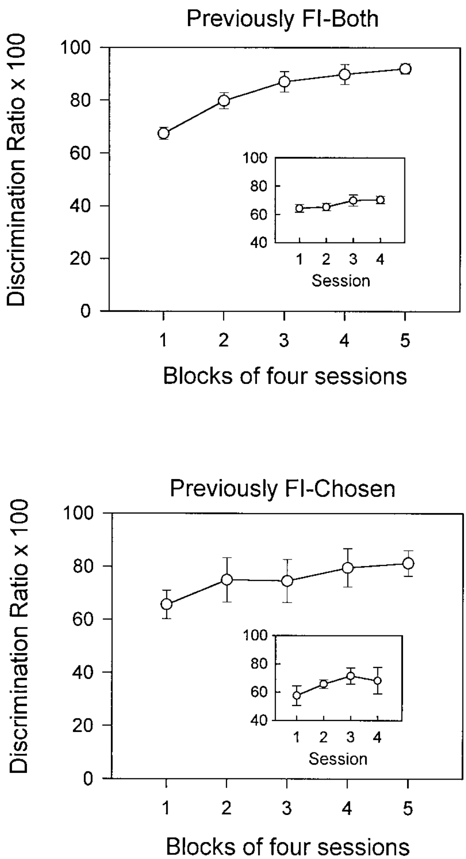

FIG. 3. Acquisition of the successive task in birds previously trained on the FI-Both (top) and FI-Chosen (bottom) tasks in Experiment 1b. (Inset) Accuracy during the first four sessions on the successive task. Error bars indicate standard error of the mean.

on short-sample trials at the 0-s delay and that accuracy on short- and long-sample trials did not differ at each of the two longer delays. The interaction between Delay and Sample Duration was not significant during the second delay test, $F(2,6) = 2.16$.

Discussion

In contrast to the complete lack of positive transfer observed by Grant and Spetch (1991) in birds transferred from the standard choice task to the successive task, birds transferred from the modified choice tasks to the successive task appeared to show moderate levels of transfer. Although birds in the present experiment did not immediately show high levels of accuracy when transferred to the successive task, their performance was above chance during

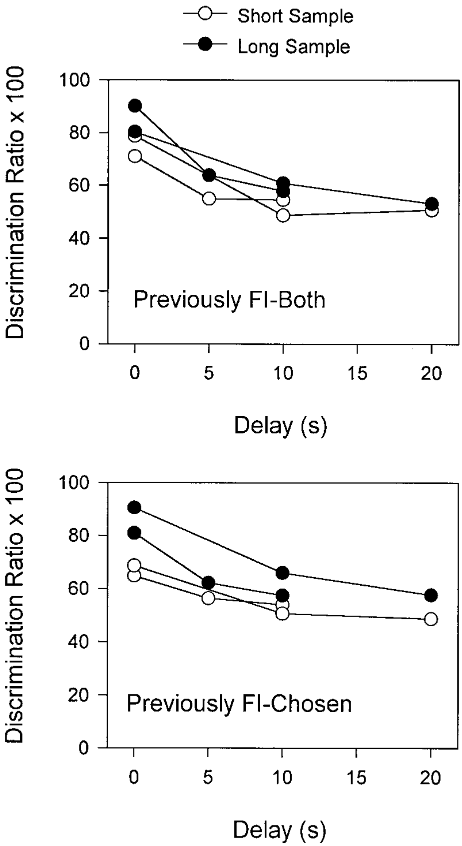

FIG. 4. Accuracy on the successive task as a function of delay on short-sample trials and long-sample trials for birds previously trained on the FI-Both (top) and FI-Chosen (bottom) tasks in Experiment 1b.

the first session or first block of sessions, and reached high levels of accuracy in relatively few sessions.

Despite showing some moderate positive transfer, the pigeons performed differently in response to delay manipulation on the successive task than they had on either of the two modified choice tasks. Rather than showing a strong respond-short effect at the longer delays as had been shown on the modified choice tasks, the birds showed either a symmetrical decline in accuracy on short and long sample trials as the delay increased, or a slight respond-long tendency at the shortest delay that decreased over the retention interval. In either case, the retention functions are very different than those previously obtained in the modified choice tasks, which suggests that different memory processes operate in the successive task.

EXPERIMENT 2a

Experiment 1 clearly indicated that the factor responsible for the difference in memory processes operating in the choice and successive tasks is not temporal in nature. That is, equating the choice and successive tasks in terms of the interval schedule during the test period did not lead to equivalent results during delay testing. It appears that some factor other than the temporal parameters of the test period is responsible for the difference in memory performance in these two tasks.

Experiment 2a tested the possibility that the critical factor is the simultaneous versus successive exposure to the two test stimuli (see Grant & Spetch, 1991). In the choice task, both test stimuli are presented simultaneously, whereas in the successive task, they are presented on separate trials and are never seen together. In this experiment we designed a task in which the test stimuli that were differentially associated with the two sample durations were presented successively, as they are in the successive task. However, to render the task similar to the choice task in other ways, a choice component was added by providing an ''option'' stimulus on each trial. Reinforcement for pecking the option stimulus was not correlated with which sample was presented, but did depend on the combination of the sample and test stimulus. Specifically, choice of the option stimulus was reinforced only when the test stimulus presented on that trial was negative. Thus, as in the typical choice procedure, the pigeons could obtain food on each trial if they responded accurately. In the present task, accurate performance would consist of choosing the test stimulus when it was positive and choosing the option stimulus when the test stimulus was negative.

Method

Subjects

Four naive Silver King pigeons (*C. livia*), each between 6 and 12 months old, served as subjects for this experiment. They were housed and maintained in the fashion described in Experiment 1a.

Apparatus

The apparatus was the same as described in Experiment 1a.

Procedure

Preliminary training. Each subject was trained to eat from the magazine and to peck at red and green illuminations of the left key and yellow illumination of the right key using the procedures described in Experiment 1a.

Baseline (0-s delay) training. Each trial began with the presentation of the houselight for either 2 s (''short'' sample) or 10 s (''long'' sample). Immediately following sample termination (i.e., 0-s delay), a red or a green test stimulus was presented on the left pecking key, and a yellow option stimulus

TABLE 1
An Example of the Contingencies in Effect for the Successive/Option Procedure of Experiment 2a

Sample	Test stimulus	Option stimulus
2 s	Red+	Yellow−
2 s	Green−	Yellow+
10 s	Red−	Yellow+
10 s	Green+	Yellow−

Note. The contingencies in effect on the test stimulus following short and long samples were counterbalanced across subjects.

was presented on the right pecking key. The red and green test stimuli were presented equally often after each sample duration in each session. For two birds, red was positive after short samples and negative after long samples, whereas green was negative after short samples and positive after long samples. For the remaining two birds, these contingencies were reversed. For all birds, the yellow option stimulus was positive only when the red or green test stimulus was negative. An example of the contingencies in effect across the four possible combinations of sample and test stimulus is shown in Table 1. The test and option stimuli were presented for an FI 5-s schedule; the first response to either stimulus after the 5 s had elapsed terminated both stimuli. If the trial terminated with a correct choice, 4-s access to mixed grain was provided as reinforcement. If the trial terminated with an incorrect choice, the ITI began immediately. The ITI, during which the chamber was dark, was 45 s.

Each session consisted of 48 trials, and all subjects received a minimum of five blocks of four training sessions. Accuracy was measured separately for the test stimuli and the option stimulus and for short and long samples. In each case, accuracy scores were calculated for the first peck (initial peck accuracy), the last peck (terminal peck accuracy), and total pecks (discrimination ratios). Test stimulus accuracy measures were determined by dividing correct pecks to the positive test stimulus by correct pecks to the positive test stimulus plus incorrect pecks to the option stimulus. Option stimulus accuracy measures were determined by dividing correct pecks to the option stimulus by correct pecks to the option stimulus plus incorrect pecks to negative test stimulus. A subject was moved to the testing phase of the experiment when: (1) mean terminal peck accuracy met or exceeded 80% correct on two consecutive blocks of four sessions and (2) the mean discrimination ratios met or exceeded .75 for both the test stimuli and the option stimulus during these blocks.

Delay test 1 (0-, 5-, 10-s delays). Each subject was given eight test sessions in this series. Sessions were identical to training sessions except that longer delays between sample termination and presentation of the test and option stimuli occurred on randomly selected trials. The delay was 5 s on 12 trials, 10 s on 12 trials, and 0 s on 24 trials in each session. Short- and long-sample trials occurred equally often at each of the three delays, and presentation of the positive and negative test stimuli on the left key was balanced within delay intervals. At all delays, contingencies were identical to those of a subject's baseline training. After the final test session, birds were returned to baseline training until terminal peck accuracy was at or above 80% correct and discrimination ratios equaled or exceeded .75 for two consecutive sessions.

Delay test 2 (0-, 10-, 20-s delays). This phase was identical to the first delay test except that test trials consisted of 0-, 10-, and 20-s delay intervals (24 trials at 0-s delay and 12 trials each at 10- and 20-s delays).

Results

Acquisition on this task was slow. One bird failed to meet the accuracy criteria within 240 sessions and was replaced by another naive bird. The four birds that acquired the task required between 76 and 168 sessions to meet the accuracy criteria.

Initial peck accuracy, terminal peck accuracy, and total peck accuracy (discrimination ratios) all showed a similar pattern and therefore only total peck accuracy is reported. Figure 5 shows accuracy on short- and long-sample trials as a function of delay interval during the two test series for the test stimulus, the option stimulus, and for the two combined (overall). In each case, accuracy declined substantially more on long-sample trials than on short-sample trials as the delay increased.

An ANOVA conducted on the overall accuracy revealed significant Delay by Sample Duration interactions during both delay tests (Delay test 1, $F(2,6) = 21.98$; Delay test 2, $F(2,6) = 15.54$). Subsequent multiple comparisons (Turkey's HSD test) showed significantly higher accuracy on short-sample trials than on long-sample trials at the 5- and 10-s delays in Delay Test 1 and at the 10- and 20-s delays during Delay Test 2. Accuracy did not differ significantly on short- and long-sample trials at the 0-s delay during either delay test.

Discussion

The addition of an option stimulus to the successive task produced results that are similar to those in a typical choice task (i.e., asymmetrical retention functions). In this option task, the red and green test stimuli, whose valence depended on the sample duration, were never presented simultaneously. Thus, as in the standard successive procedure, subjects could not view and compare these test stimuli. The valence of the option stimulus did not depend on the sample, but instead depended only on the sample–test stimulus combination and hence could be determined only by first determining whether the test stimulus was positive or negative. In this sense then, evaluation of the test

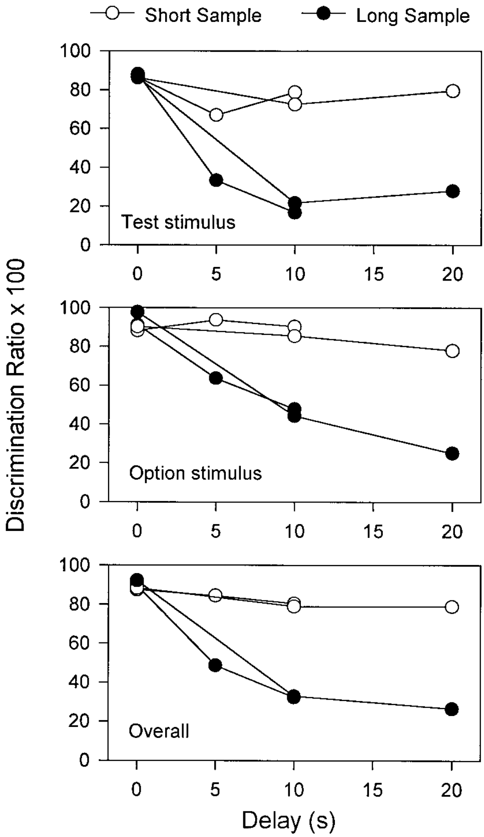

FIG. 5. Accuracy on the successive/option task as a function of delay on short-sample trials and long-sample trials in Experiment 2a. (Top) Accuracy for the red and green test stimuli, (middle) accuracy for the yellow option stimulus, (bottom) overall accuracy, averaged across the test and option stimuli.

stimulus had to be performed in isolation during a test period just as it is in the successive procedure. The opportunity to view simultaneously and compare the test stimuli therefore does not appear to be important for the emergence of the respond-short effect.

EXPERIMENT 2b

In this experiment we transferred the birds from the successive/option procedure to the standard successive task. Procedurally, this entailed the removal of only the yellow option stimulus. We wondered whether pigeons would continue to respond with high levels of accuracy to the red and green test stimuli when the option stimulus was removed and whether they would

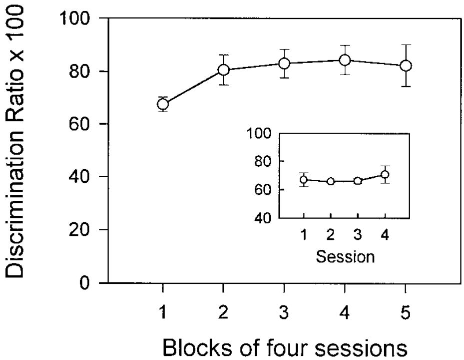

FIG. 6. Acquisition of the successive task in birds previously trained on the successive/option task in Experiment 2b. (Inset) Accuracy during the first four sessions of training on the successive task. Error bars indicate standard error of the mean.

then show a respond-short effect during delay testing in the standard successive task.

Method

Subjects and Apparatus

The subjects and apparatus were the same as those used in Experiment 2a.

Procedure

The successive procedure used for this experiment was identical to that used in Experiment 2a except that the option stimulus, and its associated reinforcement contingency, was removed. Only the red or green test stimulus was presented on each trial. When the test stimulus was positive, completion of an FI 5-s schedule resulted in food reinforcement, and when it was negative the trial terminated without food after 5 s. For each bird the relationships between sample durations and test stimuli were the same as in Experiment 2a. Each bird was trained with a 0-s delay for a minimum of five blocks of four sessions and until mean accuracy (discrimination ratio $\times$ 100) was 80% or greater for two consecutive blocks.

Each bird then received two series of delay testing, one with delays of 0, 5, and 10 s and one with delays of 0, 10, and 20 s. Other than the use of a standard successive procedure, these delay testing phases were conducted in a fashion identical to those described in Experiment 2a.

Results

Two birds satisfied the accuracy criterion within the first 20 sessions, one bird required 24 sessions, and one bird required 32 sessions. Figure 6 shows mean accuracy during the first five blocks of four sessions, with the inset

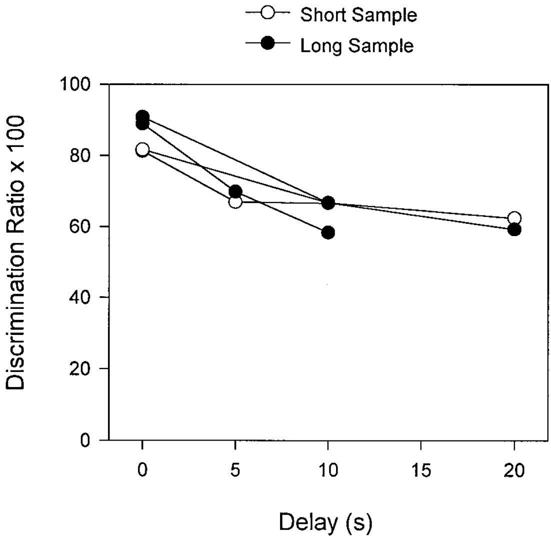

FIG. 7. Accuracy on the successive task as a function of delay on short-sample and long-sample trials in birds previously trained on the successive/option task in Experiment 2b.

graph showing mean accuracy during the first four of these sessions. Accuracy was above chance on the first session, $t(3) = 3.51$, and during the first block of sessions, $t(3) = 6.28$. Accuracy improved across blocks, $F(4,12) = 3.36$.

Figure 7 shows that accuracy during the delay tests was very different from that previously seen in the successive/option procedure. The discrimination ratios declined on both short- and long-sample trials as a function of delay, and there was no evidence of a strong respond-short tendency at the longer delays. The Delay by Sample Duration interaction was significant during the first delay test, $F(2,6) = 11.26$, but multiple comparisons (Tukey's HSD) indicated that accuracy on short-sample trials did not differ from accuracy on long-sample trials at any of the three delay intervals. The Delay by Sample Duration interaction was not significant during the second delay test, $F(2,6) = 3.12$.

Discussion

Pigeons transferred from the successive/option task to the standard successive task achieved moderate levels of accuracy on the first session, indicating some degree of positive transfer. Nevertheless, the striking difference between the symmetrical retention functions in the successive task (Fig. 7) and the asymmetrical functions in the successive/option task (Fig. 5) suggests that removal of the option stimulus altered the way pigeons retained sample duration.

GENERAL DISCUSSION

These experiments ruled out several possible explanations for why choice and successive matching-to-sample tasks yield qualitatively different retention functions with duration samples. Experiment 1a showed that symmetrical retention functions in successive tasks are not due to the temporal component during the response portion of the trial. The occurrence of an asymmetrical retention function (i.e., the respond-short effect) characteristic of the choice task was not eliminated by the addition of an FI schedule either before (Group FI-Both) or after (Group FI-Chosen) the choice response that determined reinforcement. Thus, no support was found for the possibility that timing of an FI might interfere with the retrospective code thought to mediate the respond-short effect.

Experiment 1a also suggested that the relative amount of time spent in the presence of the sample compared to that spent in the presence of the test stimuli is not a critical determinant of the respond-short effect. In the standard choice procedure, subjects typically spend much more time in the presence of the sample (e.g., with 2- and 10-s samples, 6 s on average) than in the presence of the choice stimuli (the latency to make a single choice peck). In the standard successive procedure, the FI/FT schedule for the test stimuli means that the time spent in the presence of the test stimuli is similar to the average time spent in the presence of the sample. The results of Experiment 1a, showing a respond-short effect despite temporal parameters that were similar to the standard successive procedure, indicated that this factor is not important in the emergence of a respond-short effect.

Experiment 2a ruled out the possibility that the critical difference between the choice and successive tasks is that the choice task provides the opportunity to view the test stimuli simultaneously, whereas the successive task allows only individual viewing of the test stimuli. Birds in the successive-option procedure could view the test stimuli only individually, yet showed a large respond-short effect.

It appears, instead, that the critical feature that determines whether or not asymmetrical retention functions occur is the opportunity to make a choice response. Adding a choice opportunity in the form of an option stimulus to the successive task resulted in the asymmetrical retention functions typical of the choice procedure. It should be emphasized that the contingency in effect for the option stimulus itself was not correlated with which sample stimulus was presented, but instead depended on the combination of the sample and test stimulus. The feature of the successive/option task that was more similar to the standard choice task than to the standard successive task was the opportunity to make a choice response. When the option stimulus was subsequently removed, thereby making the task into a standard successive procedure, the retention functions became symmetrical as is typical for the successive task.

In summary, it appears that asymmetrical retention functions occur in any of a variety of tasks in which retention of duration information is expressed by choice behavior, but that symmetrical retention functions occur in the successive task in which retention is expressed by responding or not responding. A caveat to this generalization, however, is that asymmetrical retention functions are not obtained in the choice task if pigeons are first trained in the successive task (Grant & Spetch, 1991). In addition, use of a many-to-one sample to test stimulus mapping arrangement in the choice task also has been found to result in symmetrical rather than asymmetrical retention functions (Grant & Spetch, 1993; Santi, Bridson, & Ducharme, 1993). These findings indicate that the difference in retention functions obtained when naive birds are tested in standard choice and successive tasks is not a reflection of differences between the way in which accuracy is assessed (i.e., using percentage correct versus a discrimination measure). Instead, it appears that the coding processes that emerge in the successive task are fundamentally different than those normally used in tasks involving a choice response, but that they are transferable and can be used in a choice task.

Although this research isolates which differences between the choice and successive task do and do not play a role in the qualitatively different retention functions for duration samples that emerge in the two tasks, it does not directly answer the question of why the retention functions are different. However, given that the respond-short effect occurred with naive birds in all tasks involving a choice opportunity, the critical feature of the successive task that leads to symmetrical retention functions appears to be the absence of an opportunity to make a choice response. This suggests the possibility that inhibitory processes may be important. Specifically, accurate performance in the successive task may require that responding be actively inhibited throughout presentation of a negative test stimulus (typically 5 s). In contrast, accurate performance in a choice task requires, at most, only momentary inhibition of responding. Perhaps the difference in the extent to which, or the duration for which, responding must be actively inhibited plays a critical role in determining coding processes. In particular, it may be that procedures which demand sustained inhibition of responding particularly emphasize instructional aspects of the task (e.g., after a short sample, respond to test stimulus A but do not respond to test stimulus B; after a long sample, respond to test stimulus B but do not respond to test stimulus A). This may encourage instructional (prospective) coding rather than retrospective coding of the samples.

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Received May 15, 1995
Revised August 23, 1995