

The Role of Asymmetrical Coding of Duration Samples in Producing the Choose-Short Effect in Pigeons

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Pigeons were trained on two independent matching-to-duration-samples tasks; one involved 2- and 10-s durations and color choice stimuli, and the other involved 4.5- and 22.5-s durations and line choice stimuli. Accuracy was above chance on mixed-choice probes in which either of the short-duration samples was followed by the two short-associated stimuli. Following explicit training on mixed-choice trials involving choice between the two short- and the two long-associated stimuli, a choose-short effect was demonstrated with both sets of duration samples. These findings are inconsistent with the possibility that the choose-short effect reflects processes of asymmetrical-sample coding and default responding. © 1994 Academic Press, Inc.

A number of studies have employed a delayed symbolic matching-to-sample task to investigate memory for event duration in pigeons (e.g., Grant & Spetch, 1991, 1993a; Spetch & Wilkie, 1982, 1983). In a typical experiment, trials begin with presentation of an overhead houselight for either a short (e.g., 2 s) or a long (e.g., 10 s) duration. Termination of the duration sample is followed by the simultaneous illumination of two pecking keys for a choice. Choice of one key (e.g., illuminated red) is reinforced if the sample had been short, and choice of the alternative key (e.g., illuminated green) is reinforced if the sample had been long.

Following acquisition of this task, memory for duration is assessed by interpolating a delay interval of varying length between termination of the sample and onset of the choice keys. Several studies have revealed a pronounced asymmetry in the retention functions on short-sample and long-sample trials (e.g., Grant & Spetch, 1991, 1993a; Kraemer, Mazmanian, & Roberts, 1985; Santi, Ducharme, & Bridson, 1992; Spetch,

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1987; Spetch & Rusak, 1989, 1992; Spetch & Wilkie, 1982, 1983). Specifically, as retention interval is lengthened, accuracy decreases markedly on long-sample trials but remains relatively constant on short-sample trials. This effect is referred to as the *choose-short effect* because the probability of choosing the short-associated stimulus increases as a function of delay.

Pigeons also demonstrate asymmetrical retention functions when samples of food (3-s access to grain) and no food (nothing or 3-s timeout) are employed in delayed symbolic matching-to-sample (Colwill, 1984; Grant, 1991; Maki, Olson & Rego, 1981; Sherburne & Zentall, 1993a, 1993b; Wilson & Boakes, 1985). Specifically, as retention interval is lengthened, accuracy decreases markedly on food-sample trials but remains relatively constant on no-food-sample trials. This effect will be referred to as the *choose-no-food effect* because the probability of choosing the no-food-associated stimulus increases as a function of delay.

Thus, both the choose-short effect and the choose-no-food effect involve asymmetrical retention in which forgetting is rapid on trials initiated by one of the two samples (i.e., long sample or food sample), and is negligible on trials initiated by the other sample (i.e., short sample or no-food sample). Another empirical similarity between the two phenomena is that neither the choose-short effect nor the choose-no-food-effect is obtained following training in which two or more samples are associated with each choice stimulus (a many-to-one sample-to-comparison mapping arrangement). Following such training, Grant (1991, Experiment 2) obtained similar rates of forgetting on trials initiated by samples of food and no food, and Grant and Spetch (1993a, Experiment 2) obtained similar rates of forgetting on trials initiated by short and long samples.

In spite of the striking empirical similarity between the choose-short and choose-no-food effects, theoretical analysis of these phenomena has proceeded independently. Three prominent theoretical analyses of the choose-short effect have been offered. Two of these theories maintain that both samples are coded, either retrospectively as perceived duration (e.g., Grant & Spetch, 1993a; Spetch & Wilkie, 1983) or prospectively as an instruction to respond to a particular choice stimulus (Kraemer *et al.*, 1985). According to the retrospective-coding model, the choose-short effect arises because a process of subjective shortening operates during the delay and causes remembered duration to appear shorter after longer delays. According to the prospective-coding model, the choose-short effect arises because the code activated by the sample is likely to be forgotten after a long delay and, in the absence of an active code, pigeons typically respond to the short-associated stimulus.

A third theoretical conception of animal timing eschews the notion that choice behavior is controlled by an internal representation and instead posits that samples differing in duration exert control over choice behavior through the adjunctive behaviors which they generate (Killeen & Fetterman, 1988). According to this theory, the choose-short effect arises be-

cause behavior reverts during a delay interval to a state similar to that present after a short sample.

Thus, the theories considered above differ with regard to the processes mediating both accurate performance in the matching-to-duration task and the choose-short effect. Of particular relevance to the present research, however, is that in spite of these differences, the three theories share the assumption that both short and long samples exert control over choice responding. These theories may be referred to as *symmetrical-sample-control theories* to emphasize that both samples are held to exert control over choice responding.

In contrast, the dominant theoretical account of the choose-no-food effect does not share the assumption that both samples exert control over choice behavior (Colwill, 1984; Grant, 1991, 1993; Sherburne & Zentall, 1993a, 1993b; Wilson & Boakes, 1985; but see Wixted, 1993). Instead, this account posits that only the food sample exerts control over choice behavior. Hence, this theory may be referred to an *asymmetrical-sample-control theory* to emphasize that only one of the samples is held to exert control over choice responding. According to this view, the choose-no-food effect arises because (a) the food sample, but not the no-food sample, is coded (asymmetrical coding) and (b) responding to the no-food-associated choice stimulus occurs when no code is active in working memory (default response rule). Because the code activated by presentation of a food sample is unlikely to remain active throughout a long delay interval, the default response rule is more likely to control choice responding at longer delays, leading to an increased tendency to choose the no-food-associated stimulus on long-delay trials.

Thus, different theoretical mechanisms have been offered as accounts of the asymmetrical retention functions obtained with duration samples and food/no food samples. However, as Grant (1993, p. 201) recently noted, the theoretical ideas developed to explain the choose-no-food effect also provide a plausible account of the choose-short effect. Specifically, it could be argued that (a) the long sample, but not the short sample, is coded and (b) responding to the short-associated choice stimulus occurs when no code is active in working memory. According to the asymmetrical-sample-control account of the choose-short effect, because the code activated by presentation of a long sample is unlikely to remain active throughout a long delay interval, the default response rule would lead to an increased tendency to choose the short-associated stimulus on long-delay trials. The present investigation tested the asymmetrical-sample-control account of the choose-short effect.

EXPERIMENT 1

Pigeons were trained in a duration matching task in which asymmetrical coding and default responding could mediate accurate performance (see left column in Table 1). Two matching-to-duration tasks were employed;

TABLE 1
Trial Types Employed During Training and
Probe Testing in Experiment 1

Training trials	Mixed-choice probe trials
2 s: G+/R-	2 s: G+/H-
10 s: R+/G-	4.5 s: H+/G-
and	and
4.5 s: H+/V-	10 s: R+/V-
22.5 s: V+/H-	22.5 s: V+/R-

Note. Numbers followed by "s" indicate the duration, in seconds, of the overhead house-light sample. Letters following the colon refer to the choice stimuli, (+) denotes correct and (-) denotes incorrect choice stimulus. Choice responses on mixed-choice probe trials were not reinforced. G, green; R, red; H, horizontal line; V, vertical line. Balancing of correct choice stimulus within each set of samples is not shown.

one involved 2- and 10-s samples and the other involved 4.5- and 22.5-s samples. Durations of 2 and 10 s were employed as one set of samples because previous studies in our laboratories have revealed a robust choose-short effect when these durations are employed as samples (e.g., Grant & Spetch, 1991, 1993a).

Two considerations led to the selection of durations of 4.5 and 22.5 s for the second problem. First, our primary consideration was to equate the discriminability between the short and long samples within each set. Because pigeons judge pairs of different absolute durations as equally discriminable when the ratio of those durations is equivalent (e.g., Dreyfus, Fetterman, Smith, & Stubbs, 1988), the 1:5 short-to-long ratio was maintained for the durations in the longer set of samples. Second, in selecting a longer set of samples it also seemed desirable that (a) the shorter duration in the longer pair be approximately equally discriminable from the short and long durations of the shorter pair and (b) the longer duration in the shorter pair be approximately equally discriminable from the short and long durations of the longer pair. Because the geometric mean between two durations approximates the point of subjective equality between those durations (e.g., Spetch & Wilkie, 1983; Stubbs, 1968), these goals were accomplished by employing durations of 4.5 and 22.5 s for the longer pair. Condition "a" noted above was fulfilled because 4.5 is the geometric mean of 2 and 10, and condition "b" noted above was fulfilled because 10 is the geometric mean of 4.5 and 22.5.

Trials initiated by either the 2- or 10-s sample terminated in a choice between two colors, and trials initiated by either the 4.5- or 22.5-s sample

terminated in a choice between two line orientations. Accurate performance in this task could be achieved by coding only the longer sample in each set (i.e., 10 and 22.5 s) and by responding to the choice stimulus associated with either of the short samples (i.e., 2 and 4.5 s) by default when no code is active in memory.

Following acquisition, a retention test was administered. As anticipated, this test revealed a robust choose-short effect with both sets of samples, a result which can be explained by theories postulating either symmetrical or asymmetrical control by the samples over choice responding. In an effort to determine whether the choose-short effect was mediated by processes of symmetrical or asymmetrical sample control, pigeons next received testing on infrequent, nonreinforced "mixed-choice" probe trials (see right column in Table 1).

On some mixed-choice probes, presentation of a short sample (either 2 or 4.5 s) was followed immediately (0-s delay) by presentation of the two short-associated choice stimuli (the color associated with the 2-s sample and the line associated with the 4.5-s sample). On the remaining mixed-choice probes, presentation of a long sample (either 10 or 22.5 s) was followed immediately by presentation of the two long-associated choice stimuli (the color associated with the 10-s sample and the line associated with the 22.5-s sample).

Both views anticipate above chance accuracy on mixed-choice probes involving the two long-associated choice stimuli. This is the case because each view maintains that each of the long samples would exert control over choice behavior. The two views make different predictions, however, concerning performance on mixed-choice probes involving the two short-associated choice stimuli. If asymmetrical sample coding and default responding mediated acquisition, then accuracy on mixed-choice probes involving the two short-associated choice stimuli should be at chance (50%). This is the case because (a) no code would be present in working memory to direct responding and (b) the default response rule specifies that a response be directed toward each of the choice stimuli. If, on the other hand, each of the four samples exerted control over choice responding, as maintained by symmetrical-sample-control theories of the choose-short effect, then accuracy on mixed-choice probes involving the two short-associated choice stimuli should be above chance.

Method

Subjects

Seven adult, Silver King pigeons (*Columba livia*) were maintained at 80% of their free-feeding weight throughout the experiment. The birds had previously served as the control group in Grant and Spetch (1993a, Experiment 2; 1993b, Experiment 1) and had been trained with one of

the sets of samples and choice stimuli employed in the present experiment (2- and 10-s samples and red and green choice stimuli). In addition, they had received delay and double-sample tests with these samples and choice stimuli. The birds were maintained on a 14:10-hr light-dark cycle with light onset at 6:00 AM. Each bird received six or seven sessions per week at the rate of one session per day. Sessions were conducted in the early morning. All seven birds were run simultaneously and session starting times varied across days by no more than 30 m.

Apparatus

Seven identical chambers, the interior dimensions of which were 29 cm tall, 29 cm wide, and 24 cm deep, were employed. Three pecking keys (2.5 cm in diameter) were mounted horizontally in a row, spaced 8 cm center to center, 23 cm above the floor. A force of approximately .15 N or greater was required to operate the keys. An Industrial Electronics, Inc. (Van Nuys, CA) in-line projector was mounted behind each key and was used to project stimuli onto the pecking key. A 5.0- by 5.5-cm opening, the top of which was 10 cm below the center pecking key, provided access to a food magazine which was illuminated whenever activated. A 28-V houselight, the shield of which was adjusted such that the light emitted was directed toward the ceiling of the chamber, was mounted 4 cm above the center pecking key. Each test chamber was enclosed in a sound- and light-attenuating enclosure. Masking noise was provided by an exhaust fan within the enclosure and by white noise delivered through a speaker in the testing room. The presentation of events within the chambers and the recording of data were accomplished using a micro-computer located in a separate room.

Procedure

Training. Each session consisted of 64 delayed-matching trials separated by a variable length intertrial interval with a mean of 20 s (range = 10–30 s). Two sets of duration samples (2 and 10 s and 4.5 and 22.5 s) and two sets of choice stimuli (colors and line orientations) were employed (see left column in Table 1). The 2- and 10-s sample durations were always followed by red and green choice stimuli, and the 4.5- and 22.5-s sample durations were always followed by horizontal and vertical choice stimuli. For four birds, green was correct following a 2-s sample and red was correct following a 10-s sample, and horizontal was correct following a 4.5-s sample and vertical was correct following a 22.5-s sample. For the remaining three birds, the relation between sample duration and correct choice stimulus within each set was the reverse.

Each trial began with illumination of the center key by the preparatory stimulus (a black dot on a white background). The preparatory stimulus

was terminated by a single peck or, in the absence of a peck, terminated after 5 s. Termination of the preparatory stimulus was followed immediately by onset of the overhead houselight for either 2, 10, 4.5, or 22.5 s. Termination of the sample was followed immediately (0-s delay) by presentation of two choice stimuli, one presented on each of the outer pecking keys. A single peck on either choice stimulus terminated both stimuli. If the correct stimulus was pecked, 3-s access to grain was presented as reinforcement. If the incorrect stimulus was pecked, the trial terminated without reinforcement, and 3 s was added to the intertrial interval.

Within each session, half of the trials involved the 2-/10-s sample set and the sample was equally often 2 and 10 s. The remaining half of the trials involved the 4.5-/22.5-s sample set and the sample was equally often 4.5 and 22.5 s. The position of the correct choice stimulus was equally often left and right on trials involving each of the four duration samples. The order in which the eight trial types (four samples \times two positions of the correct choice stimulus) were presented varied randomly both within and between sessions. This procedure was in effect for 64 sessions.

To minimize any disruption in performance produced by conducting nonreinforced probe trials later in the experiment (see below), the probability of reinforcement for pecking the correct choice stimulus was gradually reduced from 1.0 to 0.5 during the remaining 44 sessions of training (Sessions 65–108). Beginning with Session 65, and continuing every eighth session thereafter, the probability of reinforcement for a correct response was reduced by .1 until the terminal probability of .5 was reached. Non-reinforced correct trials terminated in the same fashion as incorrect trials. The terminal probability of reinforcement was in effect for the final 12 sessions of training (Sessions 97–108).

Retention testing. Retention testing involved two blocks of four sessions each. Within each block, two training sessions, identical to those employed during the last 12 sessions of the training phase, preceded each retention testing session. Eight of these training sessions intervened between the two blocks of retention testing sessions. Delays of 0, 5, and 10 s were employed in the retention testing sessions of the first block, and delays of 0, 10, and 20 s were employed in the retention testing sessions of the second block.

Retention testing sessions consisted of 72 trials. One third of the trials involved a 0-s delay. On the remaining trials, one of the two longer delays, presented equally often, was interpolated between termination of the sample and presentation of the choice stimuli. Each of the four sample durations was followed equally often by each of the three delay lengths. The reinforcement contingencies on all trials were the same as during training and the probability of reinforcement for a correct choice was .5.

Position of the correct choice stimulus was balanced within each combination of sample duration and delay. All other aspects of retention testing sessions were identical to those of the final 12 sessions of training.

Mixed-choice probe testing. Four consecutive training sessions, identical to those described above, intervened between the final session of retention testing and the first session of mixed-choice probe testing. Each mixed-choice probe session was identical to those employed during the final 12 sessions of training except for the addition of 8 mixed-choice probe trials.

Probe trials were identical to training trials with two exceptions. First, as illustrated in the right column in Table 1, the two short-associated choice stimuli were presented following either of the short samples (2 and 4.5 s), and the two long-associated choice stimuli were presented following either of the long samples (10 and 22.5 s). Second, choice responses were never reinforced.

In each session, every ninth trial was a mixed-choice probe trial. Each of the four duration samples was presented on two probe trials in each session, once with the correct stimulus on the left and once with the correct stimulus on the right. Eight consecutive sessions of mixed-choice probe testing were conducted.

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

Results

Training

Because the birds had been trained previously on the 2-/10-s matching task employed here, matching accuracy on 2- and 10-s sample trials was high in the initial four-session block of training (90.3%). Because the 4.5-/22.5-s matching task was new to these birds, initial accuracy was close to chance (52.9%). Accuracy on trials with the new samples rose steadily across blocks and was 90.4% during Sessions 61-64 (the final block of training sessions which involved a probability of reinforcement of 1.0 for correct choice responses). There was no evidence of disruption in accuracy on either task as the probability of reinforcement for a correct choice response was gradually reduced from 1.0 to .5. In the final block of training (Sessions 105-108) accuracy was high on each task (96.8% on the 2-/10-s task and 92.7% on the 4.5-/22.5-s task).

Retention Testing

The results of retention testing are presented in Fig. 1. The top graph shows matching accuracy on trials initiated by the 2- and 10-s samples, and the bottom graph shows matching accuracy on trials initiated by the 4.5- and 22.5-s samples. Delays of 0, 5, and 10 s were employed in the first four retention-testing sessions, and delays of 0, 10, and 20 s were employed in the second four retention-testing sessions.

ASYMMETRICAL CODING

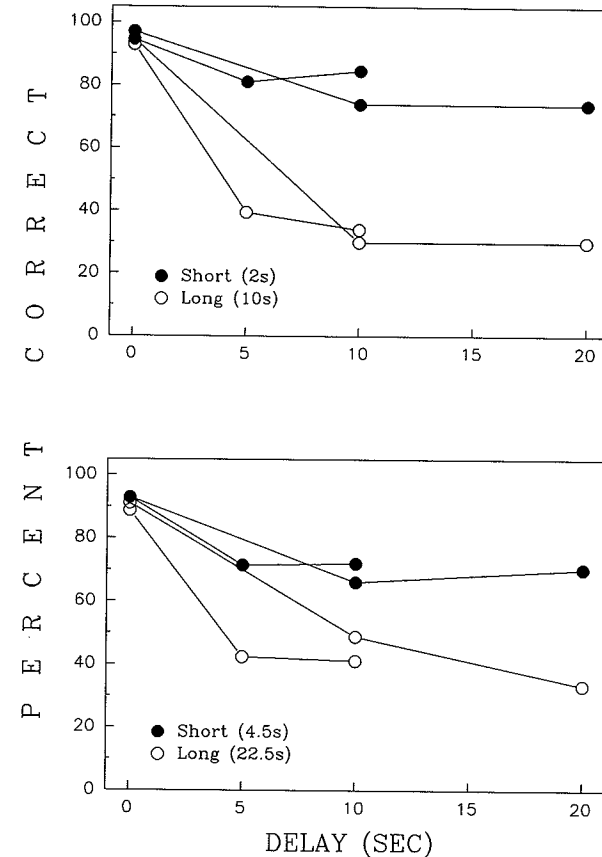


FIG. 1. The percentage of correct responses on trials initiated by the 2- and 10-s samples (top graph) and by the 4.5- and 22.5-s samples (bottom graph) as a function of delay in Experiment 1.

A strong choose-short effect is apparent with each pair of samples for both sets of delay values. In all cases, accuracy decreased markedly as a function of increases in delay on trials initiated by either of the long samples (10 and 22.5 s). In contrast, accuracy decreased only slightly as a function of delay on trials initiated by either of the short samples (2 and 4.5 s).

Separate Sample Set (2 and 10 s, and 4.5 and 22.5 s) \times Sample Duration (short and long) \times Delay Interval Analyses of Variance (ANOVAs) were performed on data obtained with each set of delay values. Both ANOVAs yielded an identical pattern of statistical significance. In reporting F values, the first is from the analysis of data obtained with delays of 0, 5, and 10 s, and the second is from the analysis of data obtained with delays of 0,

TABLE 2
Percentage of Correct Responses On Nonreinforced Mixed-Choice Probe Trials in Experiment 1

Short-associated choice stimuli	
2.0-s sample	41.1
4.5-s sample	84.0
Mean	62.6
Long-associated choice stimuli	
10.0-s sample	67.0
22.5-s sample	61.6
Mean	64.3

10, and 20 s. Both ANOVAs revealed significant main effects of sample duration, $F(1, 6) = 22.09$ and 13.20 , and delay interval, $F(2, 12) = 103.19$ and 186.66 . Importantly, the ANOVAs confirmed the reliability of the choose-short effect in that the Sample Duration \times Delay Interval interaction was significant in both cases, $F(2, 12) = 11.93$ and 15.96 . No other term in either ANOVA was significant.

Mixed-Choice Probe Testing

The percentage of correct responses on nonreinforced mixed-choice probe trials, collapsed across the 8 sessions of testing, is shown in Table 2. Two-tailed t tests revealed that accuracy on probe trials involving both the short-associated and the long-associated choice stimuli was significantly above 50%, $t(6) = 2.55$ and 2.76 , respectively. In addition, accuracy on probe trials involving the short-associated choice stimuli did not differ from that on probe trials involving the long-associated choice stimuli, $t < 1$.

Discussion

The mixed-choice probe test was designed to determine whether the choose-short effect is mediated by processes of asymmetrical coding and default responding. The results of that test are inconsistent with the view that processes of asymmetrical sample coding and default responding are responsible for the choose-short effect. Although that view correctly predicted that accuracy would be above chance on probe trials involving the long-associated choice stimuli, it incorrectly predicted that accuracy would be at chance on probe trials involving the short-associated choice stimuli.

On the other hand, the results of probe testing are consistent with the symmetrical-sample-control theories of the choose-short effect. That view correctly predicted that accuracy would be above chance on probe trials involving both the short- and long-associated choice stimuli. It should be noted also that the finding that accuracy on probe trials involving short- and long-associated choice stimuli did not differ is also consistent with

symmetrical-sample-control theories of the choose-short-effect. In particular, those accounts provide no *a priori* reason to anticipate different levels of accuracy on probe trials involving short- and long-associated choice stimuli.

The rather low level of accuracy on probe trials (63.5%, collapsed across the two tasks), relative to that on training trials presented during probe sessions (95.5%, collapsed across the two tasks), may be attributed to two factors. First, some general disruption in performance would be expected as a function of presenting unfamiliar combinations of choice stimuli on probe trials. Moreover, the level of general disruption may have been enhanced by the fact that the unfamiliar combinations of choice stimuli involved one color and one line orientation, whereas the familiar combinations always involved two colors or two line orientations. Thus, the unfamiliar combinations of choice stimuli were presumably readily discriminable from the familiar combinations of choice stimuli.

A second factor may have also led to reduced accuracy on probe trials. On probe trials, the correct and incorrect choice stimuli were associated with sample durations that differed by a factor of only 2.25 (2.0 vs 4.5 s, and 10.0 vs 22.5 s). On training trials, in contrast, the correct and incorrect choice stimuli were associated with sample durations that differed by a factor of 5.00 (2.0 vs 10.0 s, and 4.5 vs 22.5 s). Given that discriminability between durations depends upon the ratio of the two durations, rather than on the absolute difference between the durations (e.g., Cheng & Roberts, 1991; Dreyfus *et al.*, 1988; Stubbs, 1968), it is reasonable to maintain that the discrimination required at the time of responding to the choice stimuli was more difficult on probe trials than on training trials.

The finding that accuracy was considerably higher on 4.5-s sample probes than on 2-s sample probes is less readily explained. Although this finding could be accommodated by postulating a preference for line as opposed to color choice stimuli, this account is contradicted by performance on probe trials involving long-associated choice stimuli. Because a preference for responding to line choice stimuli should operate equivalently on probe trials involving short- and long-associated choice stimuli, accuracy on probe trials involving long-associated choice stimuli should have been considerably higher when the sample was 22.5 s (because the line choice stimulus was correct) than when the sample was 10 s (because the color choice stimulus was correct). In fact, a trend in the opposite direction occurred; accuracy level on probe trials involving the long-associated choice stimuli was somewhat higher when the sample was 10 s than when the sample was 22.5 s. It therefore appears unlikely that differential accuracy on 2- and 4.5-s probe trials reflected a preference for responding to line-orientation choice stimuli. At present, we are unable to suggest a viable explanation of the differential levels of accuracy on 2- and 4.5-s probe trials.

EXPERIMENT 2

The present experiment involved a further attempt to determine whether the choose-short effect arises from processes of asymmetrical coding and default responding. In the present experiment, the pigeons were *trained* to respond accurately on mixed-choice trials. This was accomplished by increasing the proportion of mixed-choice trials in each session to .50 and by reinforcing responding to the correct choice stimulus (denoted by the "+" in Table 1). The remaining trials within each training session were identical to training trials in Experiment 1.

It is important to note that the pigeons could not perform accurately on mixed-choice trials involving the short-associated choice stimuli if neither short sample (2 and 4.5 s) was coded; at the least, one of the two short samples would have to be coded. Specifically, accurate performance could be mediated by (a) coding only the 4.5-, 10-, and 22.5-s samples and (b) responding to the choice stimulus associated with the 2-s sample by default when no code is present. Alternatively, accurate performance could be mediated by (a) coding only the 2-, 10-, and 22.5-s samples and (b) responding to the choice stimulus associated with the 4.5-s sample by default when no code is present.

Following attainment of satisfactory levels of accuracy on mixed-choice trials, the retention test which followed training in Experiment 1 was replicated. If processes of asymmetrical coding and default responding are necessary to the occurrence of the choose-short effect, then the replication of the retention test should fail to produce a choose-short effect with at least one of the two sets of duration samples. If the 4.5-s sample, but not the 2-s sample, was coded, then a choose-short effect should occur during testing with 2- and 10-s samples and should not occur during testing with 4.5- and 22.5-s samples. If, on the other hand, the 2-s sample, but not the 4.5-s sample, was coded, then a choose-short effect should occur during testing with 4.5- and 22.5-s samples and should not occur during testing with 2- and 10-s samples. Finally, if training on mixed-choice trials caused the asymmetrical-coding-and-default-responding strategy to be abandoned entirely, and if this strategy is necessary for the emergence of a choose-short effect, then the choose-short effect should fail to occur with both sets of samples.

Method

Subjects and Apparatus

Same as in Experiment 1.

Procedure

Training. Sessions consisted of 96 trials. Half of the trials were identical to training trials during the final 12 training sessions in Experiment 1 (see

left column in Table 1). Each of the four sample durations occurred on 12 of these trials per session, and position of the correct choice stimulus was balanced within sample duration. The remaining 48 trials per session were identical to the mixed-choice probe trials employed in Experiment 1 (see right column in Table 1) with the exception that correct choice responses were always reinforced. Each of the four sample durations occurred on 12 mixed-choice trials per session, and position of the correct choice stimulus was balanced within sample duration. The order in which the trial types were presented varied randomly from session to session. Each bird received 120 sessions of training. All other aspects of procedure were the same as in Experiment 1.

Retention testing. With one exception, this phase was identical in all aspects to retention testing in Experiment 1. The exception was that training sessions interpolated between retention testing sessions were identical to those which preceded retention testing in Experiment 2 rather than to those which preceded retention testing in Experiment 1.

Results

Training

On the first block of training (Sessions 1-4), accuracy on mixed-choice trials involving short-associated choice stimuli was 63.9% (collapsed across the 2- and 4.5-s sample durations) and was 66.8% (collapsed across the 10- and 22.5-s sample durations) on mixed-choice trials involving long-associated choice stimuli. On the final block of training (Sessions 117-120), accuracy on mixed-choice trials involving short-associated choice stimuli was 83.8% (collapsed across the 2- and 4.5-s sample durations) and was 85.6% (collapsed across the 10- and 22.5-s sample durations) on mixed-choice trials involving long-associated choice stimuli. Accuracy remained high throughout training on the original training trials (approximately 95%).

Retention Testing

The results of retention testing are presented in Fig. 2. The top graph shows matching accuracy on trials initiated by the 2- and 10-s samples, and the bottom graph shows matching accuracy on trials initiated by the 4.5- and 22.5-s samples. Delays of 0, 5, and 10 s were employed in the first four retention-testing sessions, and delays of 0, 10, and 20 s were employed in the second four retention-testing sessions.

A strong choose-short effect is apparent with each pair of samples at each set of delay values. In all cases, accuracy decreased markedly as a function of increases in delay on trials initiated by either of the long samples (10 and 22.5 s). In contrast, accuracy decreased only slightly as a function of delay on trials initiated by either of the short samples (2 and 4.5 s).

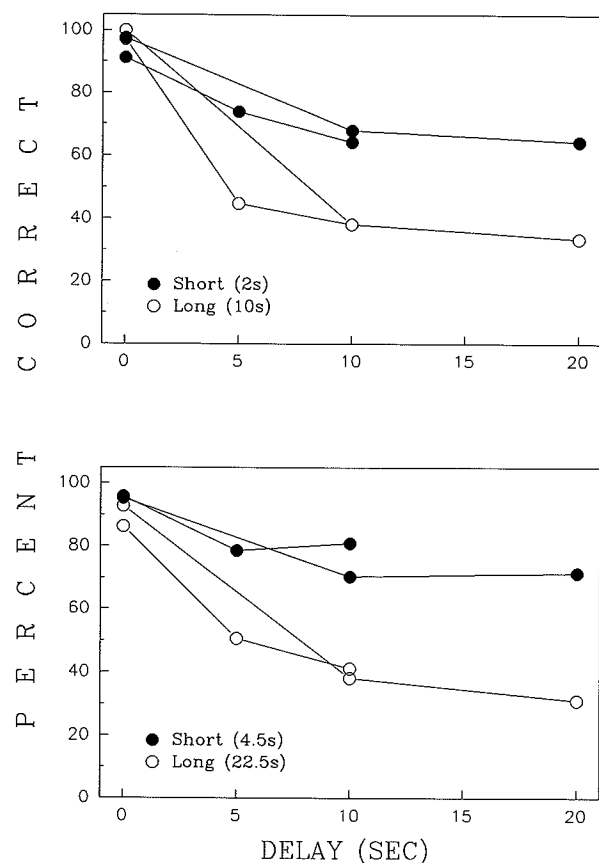


FIG. 2. The percentage of correct responses on trials initiated by the 2- and 10-s samples (top graph) and by the 4.5- and 22.5-s samples (bottom graph) as a function of delay in Experiment 2.

Separate Sample Set (2 and 10 s, and 4.5 and 22.5 s) \times Sample Duration (short and long) \times Delay Interval ANOVAs were performed on the data obtained with each set of delay values. Both ANOVAs yielded an identical pattern of statistical significance. In reporting F values, the first is from the analysis of data obtained with delays of 0, 5, and 10 s, and the second is from the analysis of data obtained with delays of 0, 10, and 20 s. Both ANOVAs revealed significant main effects of sample duration, $F(1, 6) = 27.68$ and 8.45 , and delay interval, $F(2, 12) = 73.89$ and 90.23 . Importantly, the ANOVAs confirmed the reliability of the choose-short effect in that the Sample Duration \times Delay Interval interaction was significant in both cases, $F(2, 12) = 8.39$ and 5.68 . No other term in either ANOVA was significant.

Discussion

A training regime which requires that at least one of the short-duration samples exert control over choice responding did not influence either the occurrence or magnitude of the choose-short effect. As in Experiment 1, a robust choose-short effect occurred with both sets of samples and with both sets of delay intervals. These findings contradict the view that processes of asymmetrical coding and default responding produce the choose-short effect. If that view was correct, then retention testing should have revealed either no choose-short effect with either set of samples or a choose-short effect with only one set of samples.

GENERAL DISCUSSION

The present experiments investigated the possibility that processes of asymmetrical-sample coding and default responding, previously invoked to account for the choose-no-food effect obtained in studies assessing retention of food and no-food samples (Colwill, 1984; Grant, 1991; Sherburne & Zentall, 1993a, b; Wilson & Boakes, 1985), might also provide an adequate interpretation of the choose-short effect obtained in studies assessing retention of short- and long-duration samples (e.g., Spetch, 1987; Spetch & Wilkie, 1983). When applied to the matching-to-duration task, this account maintains that only the long sample is coded and that responding to the short-associated choice stimulus occurs whenever no code is active in working memory.

Two tests of this interpretation of the choose-short effect were reported. In the first, conducted in Experiment 1, pigeons received initial training on two independent matching-to-duration tasks in which different sample durations and choice stimuli were employed in each task. Following a retention test which yielded a robust choose-short effect with both sets of samples, pigeons received nonreinforced probe tests in which either of the two short samples was followed by the two short-associated choice stimuli, and either of the two long samples was followed by the two long-associated choice stimuli. If the choose-short effect is produced by processes of asymmetrical coding and default responding, then accuracy on these mixed-choice probes should have been at chance when the test involved the two short-associated choice stimuli. Instead, accuracy was above chance on these probes and was equivalent to that on probes involving the two long-associated choice stimuli.

In the second test, conducted in Experiment 2, pigeons were trained to respond accurately on mixed-choice trials involving the two short- and the two long-associated choice stimuli. In order to acquire this task, at least one of the short-duration samples must exert control over choice responding. If the choose-short effect is produced by processes of asymmetrical coding and default responding, then a replication of the retention

test conducted in Experiment 1 should have failed to reveal a choose-short effect with at least one of the two sets of samples. In contrast to this prediction, a robust choose-short effect was obtained with both sets of samples.

The failure to confirm predictions derived from the asymmetrical-sample-control account reported in this article suggests that the choose-short effect is a function of processes other than asymmetrical-sample coding and default responding. Also supporting this conclusion is Spetch's (1987) finding that pigeons make choose-long errors when tested at a retention interval shorter than that employed in training. In that study, 2- and 8-s presentations of grain served as the duration samples. Following extended training with a fixed retention interval of 10 s in one phase and 20 s in another phase, pigeons were tested with retention intervals both longer and shorter than that employed in training. When tested with delays longer than the training delay, the majority of errors involved choice of the short-associated choice stimulus (i.e., the typical choose-short effect). However, when tested with delays shorter than the training delay, the majority of errors involved choice of the long-associated choice stimulus (i.e., a choose-long effect). As noted by Grant (1993, p. 201), the occurrence of a choose-long effect is inconsistent with the view that processes of asymmetrical coding and default responding operated in Spetch's (1987) experiment. Had the pigeons employed a coding process in which the short sample was not coded, testing at any delay interval, whether shorter or longer than that employed in training, should reveal that the majority of errors involve selection of the short-associated choice stimulus.

Thus, the present findings and those of Spetch (1987) provide a convincing case against the hypothesis that processes of asymmetrical coding and default responding are *necessary* to the occurrence of the choose-short effect. A related issue is whether *some instances* in which the choose-short effect has been obtained might reflect these processes. Although such a possibility cannot be ruled out with certainty, we believe it is unlikely.

Consider that the training regimes employed by Spetch (1987) and in the present Experiment 1 involved the critical features thought to be conducive to the occurrence of a choose-short effect: use of a choice matching procedure in which each sample is associated with a unique correct choice stimulus (see Grant, 1993; Grant & Spetch, 1991, 1993a, 1994; Spetch & Grant, 1993). Thus, if the choose-short effect is at least sometimes mediated by processes of asymmetrical coding and default responding, then those processes should have, but apparently did not, operate in the present experiments and that of Spetch (1987). Thus, the results reported in the present article join with those reported by Spetch (1987) in suggesting that the choose-short effect is a function of processes other than asymmetrical coding and default responding. Whether a theory

based on these other processes can also be applied to account for the choose-no-food effect remains to be determined.

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