Memory for duration in pigeons: Dissociation of choose-short and temporal-summation effects

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Five groups of pigeons were trained in a symbolic choice-matching task involving short (2-sec) and long (10-sec) durations of houselight as samples. Four groups also received training with a second set of samples: line orientations or 2- and 10-sec presentations of keylight. The type of sample-to-comparison mapping varied across groups. Although only two of the five groups demonstrated a choose-short effect (a tendency to choose the comparison associated with a short sample at longer delays), all groups demonstrated temporal summation (a tendency to respond on the basis of the combined duration of two successively presented samples). Moreover, the magnitude of temporal summation was equivalent in groups that did and did not demonstrate a choose-short effect. The results suggest that the processes underlying the perception of sample duration remain invariant across different sample-to-comparison mapping arrangements, but that the memory code used to retain temporal information varies.

Several experiments have employed a choice–matching-to-sample procedure to assess short-term retention of event duration in pigeons (e.g., Grant & Spetch, 1991, 1993; Kraemer, Mazmanian, & Roberts, 1985; Spetch, 1987; Spetch & Rusak, 1989, 1992; Spetch & Sinha, 1989; Spetch & Wilkie, 1982, 1983). In a typical experiment, pigeons are reinforced for choosing one comparison stimulus (e.g., a red key) after a short (e.g., 2-sec) sample presentation and for choosing the alternative comparison stimulus (e.g., a green key) after a long (e.g., 10-sec) sample presentation.

Two phenomena, the choose-short effect and the temporal-summation effect, have been reported by investigators using the choice-matching task and duration samples. The choose-short effect refers to the finding that, as retention interval is lengthened, accuracy decreases to a much greater extent on trials initiated by a long sample than on trials initiated by a short sample (Grant & Spetch, 1991, 1993; Kraemer et al., 1985; Spetch, 1987; Spetch & Rusak, 1989, 1992; Spetch & Wilkie, 1982, 1983; Wilkie & Willson, 1990). The temporal-summation effect refers to the finding that the choice response tends to reflect the combined duration of temporal samples that are presented successively on a double-sample trial (Kraemer & Roper, 1992; Spetch & Sinha, 1989; Wilkie & Willson, 1990).

Both effects have been interpreted as reflecting analogical coding of stimulus duration. According to this theo-

retical conception, pigeons normally retain an analogical representation of sample duration in the choice task (e.g., the number of counts generated by an internal pacemaker during sample presentation), and assess duration retrospectively at the time of choice (e.g., Grant, 1993; Grant & Spetch, 1991, 1993; Spetch, 1987; Spetch & Wilkie, 1983; Spetch & Sinha, 1989; Wilkie & Willson, 1990). The choose-short effect is held to arise because the analogical representation weakens during the retention interval, resulting in a progressive shortening of remembered duration (e.g., Spetch, 1987; Spetch & Wilkie, 1983). The temporal-summation effect is held to arise because the analogical representations of successively presented duration samples are combined or summed (Spetch & Sinha, 1989; Wilkie & Willson, 1990).

Recently, however, Grant and Spetch (1993) and Santi, Bridson, and Ducharme (1993) have found that the choose-short effect is absent or diminished when the choice-matching task involves a sample-to-comparison mapping in which each duration sample shares a common comparison stimulus with some other sample. In addition, Grant and Spetch (1991) and Spetch and Grant (1993) reported that pigeons trained and tested in a successive (go/no-go) matching task with duration samples do not show a corresponding "respond-short" effect at long retention intervals.

These instances in which a choose-short effect has not been obtained suggest that, under some conditions, pigeons code duration samples nonanalogically. For example, Grant and Spetch (1991; Spetch & Grant, 1993) argued that, in successive matching, pigeons prospectively code the samples as instructions to respond and/or not to respond to particular test stimuli. Grant and Spetch (1993) and Santi et al. (1993) argued that in a many-to-one choice task, pigeons engage in some form of common coding in which samples associated with the same comparison activate a

single code (e.g., "peck red," "Sample A"). Such non-analogical codes could preclude the subjective shortening process and hence eliminate the choose-short effect.

If (1) analogical coding of duration samples is necessary to produce both the choose-short and temporal-summation effect, and (2) the lack of a choose-short effect reflects nonanalogical coding of duration samples, then temporal summation should fail to occur under conditions that eliminate the choose-short effect. Contrary to this expectation, however, Spetch and Grant (1993) and Santi et al. (1993) have reported a dissociation of the choose-short and temporal-summation effects. In both studies, temporal summation was obtained during double-sample testing even though a choose-short effect was not obtained during delay testing. Spetch and Grant obtained this dissociation in a successive-matching task; Santi et al. obtained it in a choice-matching task with a many-to-one sample-to-comparison mapping.

The demonstration of temporal summation in the absence of a choose-short effect is inconsistent with the view that both phenomena are indicative of analogical coding of duration samples. In response to this theoretical challenge, both Spetch and Grant (1993) and Santi et al. (1993) have argued that temporal summation results from nonmemorial properties of the timing system, and is independent of the coding process being used. Kraemer and Roper (1992) reached a similar conclusion and suggested that temporal summation arises because, at least on some double-sample trials, the accumulator component of an internal clock is not at zero when the pigeon begins timing the second sample (see Church, 1978, 1989; Gibbon & Church, 1984, for further specification of the internal clock model of timing). On these occasions, the duration of the second sample will be overestimated.

The experiments reported in this article provided further tests of the dissociation between the temporal-summation and choose-short effects. In the first experiment, we investigated whether temporal summation might at least be reduced in procedures that fail to produce the choose-short effect. To this end, temporal summation was assessed following training regimes known to produce the choose-short effect and following training regimes known to eliminate the choose-short effect. In the second experiment, we explored the generality of the dissociation. To this end, temporal summation was assessed following training regimes known to eliminate the choose-short effect but in which summation tests had not been previously conducted. If the temporal-summation effect results from nonmemorial properties of the timing system and is independent of the coding process being used (Kraemer & Roper, 1992; Santi et al., 1993; Spetch & Grant, 1993), then it should be obtained without decrement in these procedures.

EXPERIMENT 1

Santi et al. (1993) trained pigeons on a many-to-one choice-matching task in which one comparison stimulus was correct following either a red light or a 2-sec house-light, and the alternate comparison stimulus was correct

following either a green light or an 8-sec houselight. During delay testing, pigeons showed a symmetrical decline in accuracy as retention interval was lengthened on trials initiated by both short and long samples. During double-sample testing, however, temporal summation was obtained: pigeons tended to respond on the basis of the combined duration of the two samples.

All of the birds employed in Santi et al.'s (1993) double-sample test had been trained in the many-to-one task, so it is unclear whether their pigeons might have shown weaker temporal summation than pigeons trained in a regime that does produce a choose-short effect. In the present experiment, temporal-summation effects were compared in three groups of pigeons that had previously participated in Grant and Spetch's (1993) Experiment 2. Two of the groups (the control and one-to-one groups) had previously demonstrated a choose-short effect during delay testing. The third group (the many-to-one group) was trained in a procedure highly similar to that used by Santi et al. and had not demonstrated a choose-short effect (Grant & Spetch, 1993, Experiment 2). If temporal summation is truly independent of the way in which samples are coded, all three groups should demonstrate a temporal-summation effect of equivalent magnitude.

Method

Subjects

Twenty-four adult Silver King pigeons (*Columba livia*) were maintained at 80% of their free-feeding weights throughout the experiment. The birds were housed in individual cages with free access to water and grit. The birds were maintained on a 14:10-h light:dark cycle with light onset at 6:00 a.m. At the time of arrival in the laboratory, 8 birds had been assigned at random to each of three groups: control, OTO (one-to-one), and MTO (many-to-one). The birds had previously participated in the training and testing reported by Grant and Spetch (1993, Experiment 2). Each bird received six or seven sessions per week at the rate of one session per day. Sessions were conducted in the mid- and late morning. For each bird, session starting times varied across days by no more than 30 min.

Apparatus

Eight 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 0.15 N or greater was required to operate the keys. An Industrial Electronics, Inc. (Van Nuys, CA) in-line projector mounted behind each key was used to project stimuli onto the pecking key. A 5.0 × 5.5 cm opening, the top of which was 10 cm below the center pecking key, provided access to a food magazine that 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 microcomputer located in a separate room.

Procedure

Because of the birds' previous experience and the fact that group assignments remained the same, no preliminary training was required. Immediately following the termination of testing in Grant

and Spetch's (1993) Experiment 2, the birds received four consecutive sessions of baseline training.

Baseline training. For the birds in the OTO and MTO groups, sessions consisted of 64 trials separated by a variable intertrial interval with a mean of 20 sec (range = 10-30 sec). Each trial began with the illumination of the center key by the preparatory stimulus (a white triangle on a black background). The preparatory stimulus was terminated by a single peck or, in the absence of a peck, after 5 sec. Termination of the preparatory stimulus was followed immediately by onset of the overhead houselight on half of the trials and of a white vertical or horizontal line on a black background on the center key on the other half of the trials. The duration of the houselight was equally often short (2 sec) and long (10 sec), and the line orientation was equally often vertical and horizontal. The sample to be presented on any particular trial was determined randomly in each session with the restriction that each of the four samples (2-sec houselight, 10-sec houselight, vertical line, and horizontal line) was presented 16 times. For the birds in the control group, sessions were identical except that only the 32 temporal-sample trials were presented.

For the birds in all three groups, termination of the temporal sample was followed immediately (0-sec delay) by illumination of the two side keys, one with red light and the other with green light. A single peck on either comparison stimulus terminated both comparison stimuli. If the correct comparison was pecked, a 3-sec presentation of grain occurred as reinforcement. If the incorrect comparison was pecked, the trial terminated without reinforcement and 3 sec were added to the intertrial interval. For 4 birds in each group, red was correct on short-sample trials and green was correct on long-sample trials; for the 4 remaining birds, the contingencies were reversed. Position of the correct comparison stimulus was balanced within sample duration.

For the birds in the OTO group, the line sample terminated after 6 sec and was followed immediately (0-sec delay) by illumination of the two side keys, one with a vertical line and the other with a horizontal line. For all 8 birds, horizontal was the correct comparison on horizontal-sample trials and vertical was the correct comparison on vertical-sample trials. Correct responses were followed by 3-sec access to food; incorrect responses terminated the trial without food and 3 sec were added to the intertrial interval. For the birds in the MTO group, trials involving the line samples were the same as those for the birds in the OTO group except that red and green, rather than vertical and horizontal, were presented as comparison stimuli. For all 8 birds, green was the correct comparison on horizontal-sample trials and red was the correct comparison on vertical-sample trials. In both groups, position of the correct comparison stimulus was balanced within sample type.

Double-sample tests. Test sessions consisted of 24 single-sample trials and 24 double-sample trials. Single-sample trials were identical in all aspects to the baseline trials. On double-sample trials, termination of the preparatory stimulus was followed immediately by presentation of either a short (2-sec houselight) or long (10-sec houselight) presample. A 5-sec interstimulus interval (ISI), in which no stimuli were presented, immediately followed termination of the presample. Termination of the ISI was followed immediately by presentation of a short (2-sec houselight) or long (10-sec houselight) target sample. The comparison stimuli were presented immediately upon termination of the target sample. The correct comparison stimulus was determined by the duration of the target sample in accord with the contingencies of baseline training. Each of the four types of double-sample trials (short-short, S-S; long-short, L-S; short-long, S-L; and long-long, L-L) occurred six times within each session, and position of the correct comparison stimulus was equally often right and left on each of the four types of trials. The order in which trials occurred was determined randomly in each session. A total of four testing sessions were administered. Two baseline sessions, identical to those described above, preceded each test session.

A second test phase was identical to the first, except that the ISI separating termination of the presample and onset of the target sample was decreased from 5 to 1 sec. Eight baseline sessions intervened between the two testing phases.

Delay test. Retention testing began on the day following the end of double-sample testing. These sessions were identical for all groups and consisted of 64 trials involving duration samples: 48 with a 0-sec delay (as in training), 8 with a 10-sec delay, and 8 with a 20-sec delay between sample termination and onset of the comparison stimuli. The reinforcement contingencies on 10- and 20-sec delay trials were identical to those on 0-sec delay trials, which in turn were identical to those of training. The duration of the sample was equally often short and long at each delay, and position of the correct comparison was balanced within each combination of sample duration and delay. The order in which the different trial types appeared was determined randomly in each session.

Each bird received four sessions of retention testing, with Sessions 2-4 each preceded by two baseline training sessions.

Results

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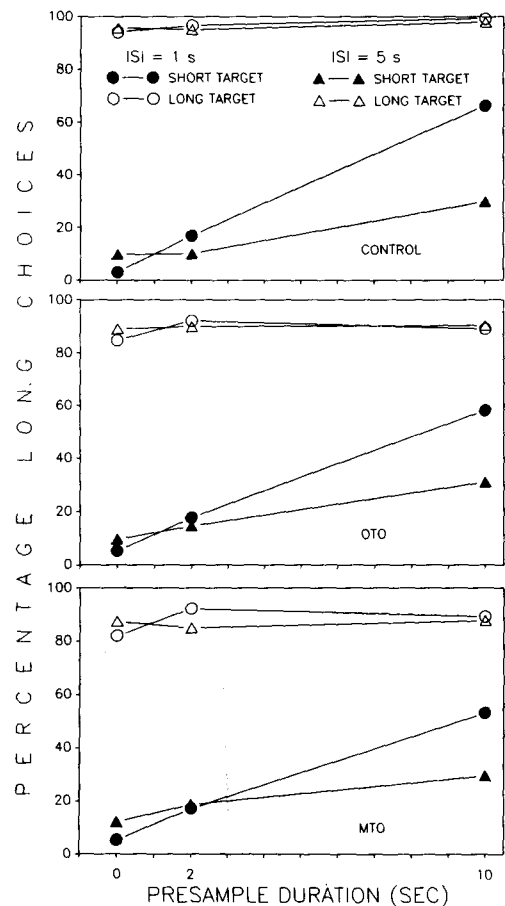

Figure 1. Percentage of choices of the comparison stimulus associated with a long sample as a function of presample duration in each group during the double-sample test in Experiment 1. Data are shown separately for each combination of ISI and target-sample duration.

Double-Sample Tests

Figure 1 shows the percentage of long choices on trials involving short and long target samples as a function of presample duration. All three groups demonstrated temporal summation in that the percentage of long choices increased as the presample duration increased from 0 sec (single-sample trials) to 10 sec. This tendency was more apparent on trials in which (1) the ISI was 1 sec rather than 5 sec, and (2) the target sample was short rather than long (presumably because the percentage of long choices was already high on single-sample trials in which the target sample was long). Importantly, the magnitude of temporal summation was approximately equivalent in the three groups.

A group (control, OTO, MTO) × target-sample duration (2 and 10 sec) × presample duration (0, 2, and 10 sec) × ISI (1 and 5 sec) analysis of variance (ANOVA) was performed on the percentage of long choices. The analysis revealed significant main effects of presample duration [$F(2,42) = 102.23$], target-sample duration [$F(1,21) = 364.93$], and ISI [$F(1,21) = 8.42$]. The presample duration × target-sample duration interaction was also significant [$F(2,42) = 89.15$]. ISI interacted significantly with both presample duration [$F(2,42) = 31.08$] and target-sample duration [$F(1,21) = 11.02$]. Neither the main effect of group nor any interactions involving the group factor were significant.

Delay Test

Retention functions on short-sample and long-sample trials in each group are shown in Figure 2. In the control and OTO groups, the retention functions were asymmetrical; accuracy declined more rapidly on trials initiated by a long sample than on trials initiated by a short sample (the choose-short effect). On the other hand, the retention functions were symmetrical in the MTO group; accuracy declined at an equivalent rate on trials initiated by a short and long sample.

A group × sample duration × delay ANOVA performed on the percentage of correct responses revealed significant main effects of sample duration [$F(1,21) = 22.10$] and delay [$F(2,42) = 380.81$]. Two interactions were also significant: sample duration × delay [$F(2,42) = 15.72$] and group × sample duration × delay [$F(4,42) = 4.95$]. Sample duration × delay ANOVAs were also performed on the data from each group separately. The sample duration × delay interaction revealed a significant choose-short effect in the control group [$F(2,14) = 12.51$] and the OTO group [$F(2,14) = 6.61$], but not in the MTO group [$F(2,14) = 2.15$].

Discussion

The results of the delay test replicated our earlier findings with these animals (Grant & Spetch, 1993, Experiment 2): the control and OTO groups demonstrated a choose-short effect, whereas the MTO group did not. These results are also consistent with those of Santi et al.'s (1993) delay tests in which a choose-short effect was obtained following training in a one-to-one procedure but not following training in a many-to-one procedure.

The results of double-sample testing in the MTO group replicate Santi et al.'s (1993) finding that a temporal-summation effect is obtained following training in which one color sample and one duration sample is associated with each of two comparison stimuli. Moreover, our finding that the magnitude of the temporal-summation effect did not differ among the three groups reveals that the magnitude of the temporal-summation effect is independent of whether or not delay testing provides evidence of a choose-short effect. This result is consistent with the proposition that the temporal-summation effect arises from nonmemorial properties of the timing system and is independent of the way in which temporal information is coded in working memory (Kraemer & Roper, 1992; Santi et al., 1993; Spetch & Grant, 1993).

EXPERIMENT 2

In Experiment 2, we employed two groups of pigeons that had previously participated in Grant and Spetch's (1993) Experiment 3. The birds in each group had been trained on a many-to-one choice-matching task in which two sets of duration samples (short and long keylight, and short and long houselight) were employed. In the consistent group, the two short samples (2-sec keylight and 2-sec houselight) were associated with one comparison (e.g., red), and the two long samples (10-sec keylight and 10-sec houselight) were associated with the alternative comparison (green, in the present example). In the inconsistent group, one comparison (e.g., red) was correct following either a short presentation of keylight or a long presentation of houselight. The alternative comparison (green, in the present example) was correct following a long presentation of keylight or a short presentation of houselight.
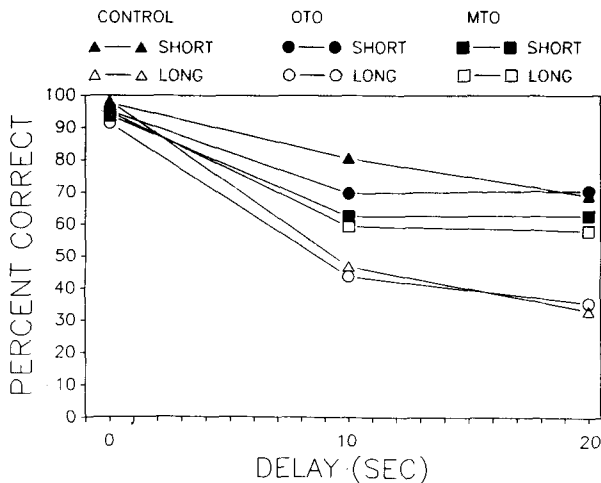

Figure 2. Percentage of correct responses on trials initiated by a short (2-sec) and long (10-sec) sample in each group as a function of delay during the delay test in Experiment 1.

Immediately prior to Experiment 2, the birds had received a test for retention of event duration involving delays of 0, 5, and 10 sec. Neither group demonstrated a choose-short effect during the retention test. In Experiment 2, we investigated whether these animals would nonetheless demonstrate a temporal-summation effect.

Method

Subjects

Sixteen adult Silver King pigeons (*Columba livia*) were maintained as in Experiment 1. At the time of arrival in the laboratory, 8 birds had been assigned at random to each of two groups: inconsistent and consistent. The birds had previously participated in the training and testing reported by Grant and Spetch (1993, Experiment 3). Each bird received six or seven sessions per week at the rate of one session per day. Sessions were conducted in the late morning. For each bird, session starting times varied across days by no more than 30 min.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

Because of the birds' previous experience and the fact that group assignments remained the same, no preliminary training was required. Immediately following the termination of testing in Grant and Spetch's (1993) Experiment 3, the birds received four consecutive sessions of baseline training.

Baseline training. Sessions consisted of 48 trials separated by an intertrial interval of 20 sec. Each trial began with the illumination of the center key by the preparatory stimulus (a black dot on a white background). The preparatory stimulus was either terminated by a single peck or, in the absence of a peck, terminated after 5 sec. Termination of the preparatory stimulus was followed immediately by onset of an overhead houselight on half of the trials and of a white "X" on a black background on the center key on the other half of the trials. The duration of the houselight and keylight was equally often short (2 sec) and long (10 sec). The sample to be presented on any particular trial was determined randomly, with the restriction that each of the four samples (2-sec houselight, 10-sec houselight, 2-sec keylight, and 10-sec keylight) was presented 12 times in each session. Termination of the sample was followed immediately (0-sec delay) by illumination of the two side keys, one with red light and the other with green light. Position of the correct comparison stimulus was balanced within sample type. A single peck on either comparison stimulus terminated both comparison stimuli. If the correct comparison was pecked, a 4-sec presentation of grain occurred as reinforcement. If the incorrect comparison was pecked, the trial terminated without reinforcement and 4 sec were added to the intertrial interval.

For the 8 birds assigned to the consistent group, one comparison stimulus (red for 4 birds and green for 4 birds) was correct on both types of short-sample trials (2-sec houselight or 2-sec keylight) and the alternative comparison stimulus was correct on both types of long-sample trials (10-sec houselight or 10-sec keylight). For the 8 birds assigned to the inconsistent group, one comparison stimulus (red for 4 birds and green for 4 birds) was correct following a short (2-sec) presentation of houselight or a long (10-sec) presentation of keylight, and the alternative comparison stimulus was correct following a long (10-sec) presentation of houselight or a short (2-sec) presentation of keylight.

Double-sample tests. Test sessions consisted of 24 single-sample trials and 24 double-sample trials. Single-sample trials were identical in all aspects to the trials of baseline sessions. On double-sample trials, termination of the preparatory stimulus was followed immediately by presentation of either a short (2-sec) or long (10-sec) presample. A 2-sec ISI, in which no stimuli were presented, im-

mediately followed termination of the presample. Termination of the ISI was followed immediately by presentation of a short (2-sec) or long (10-sec) target sample. The comparison stimuli were presented immediately upon termination of the target sample. The correct comparison stimulus was determined by the duration of the target sample in accord with the contingencies of baseline training. Each of the four types of double-sample trials (short-short, S-S; long-short, L-S; short-long, S-L; and long-long, L-L) occurred six times within each session, and position of the correct comparison stimulus was equally often right and left on each of the four types of trials. The order in which trials occurred was determined randomly in each session.

Two types of test sessions were employed: those in which keylight durations served as the samples and those in which houselight durations served as the samples. On keylight sessions, all target samples and presamples consisted of short or long presentations of keylight. On houselight sessions, all target samples and presamples consisted of short or long presentations of houselight. A total of four testing sessions were administered; two involved keylight durations (K) and two involved houselight durations (H). One baseline session (B), in which all trials were single-sample trials and both keylight durations and houselight durations were presented equally often, preceded each test session. The order of sessions was B-K-B-H-B-K-B-H.

The second test phase was identical to the first, except that the ISI separating termination of the presample and onset of the target sample was increased from 2 to 5 sec. Two baseline sessions intervened between the two testing phases. The order of sessions in the second test was identical to that in the first test.

Concurrent delay and double-sample test. Next, each bird received four sessions of concurrent delay and double-sample testing. Each test session was preceded by two baseline sessions that were identical in all aspects to those employed during training. Test sessions consisted of 32 single-sample trials and 12 double-sample trials. Only keylight durations were employed. Twenty-four of the single-sample trials involved a 0-sec delay, four involved a 5-sec delay, and four involved a 10-sec delay. The sample was equally often short (2-sec keylight) and long (10-sec keylight) at each delay interval, and position of the correct comparison was balanced within each combination of sample duration and delay.

Six of the double-sample trials involved a short presample and a short target sample (S-S), and the remaining six involved a short presample and a long target sample (S-L). These trials were identical to the S-S and S-L trials of the previous double-sample test in which keylight durations and a 5-sec ISI was employed. Position of the correct comparison stimulus was balanced within trial type. The order in which the various types of single-sample and double-sample trials occurred was determined randomly in each session.

Results

Double-Sample Tests

Figure 3 shows the percentage of long choices, collapsed across keylight and houselight samples, on trials involving short and long target samples as a function of presample duration. Both groups demonstrated temporal summation, and the effect was more marked when the ISI was 2 rather than 5 sec.

An ANOVA performed on the percentage of long choices revealed significant main effects of presample duration [$F(2,28) = 103.28$] and target-sample duration [$F(1,14) = 715.09$]. The interaction between presample duration and target-sample duration was significant [$F(2,28) = 108.26$]. ISI interacted significantly with both presample duration [$F(2,28) = 4.09$] and target-sample duration [$F(1,14) = 14.88$]. Neither the main effect of
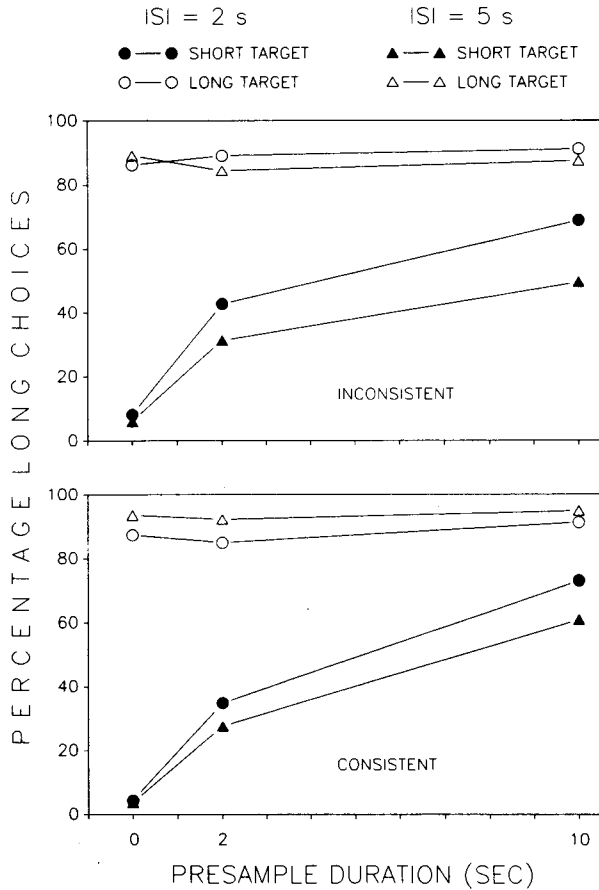
Neither the main effect of group nor any interactions involving the group factor were significant.

Discussion

The results of the delay test replicated our earlier finding with these animals (Grant & Spetch, 1993, Experiment 3); neither group demonstrated a choose-short effect during delay testing. During both double-sample tests, a temporal-summation effect was obtained in each group. These results extend the generality of the dissociation between temporal-summation and choose-short effects to situations in which the choose-short effect is eliminated by a many-to-one mapping in which all the samples are tem-

Figure 3. Percentage of choices of the comparison stimulus associated with a long sample as a function of presample duration in each group during the double-sample test in Experiment 2. Data are shown separately for each combination of ISI and target-sample duration.
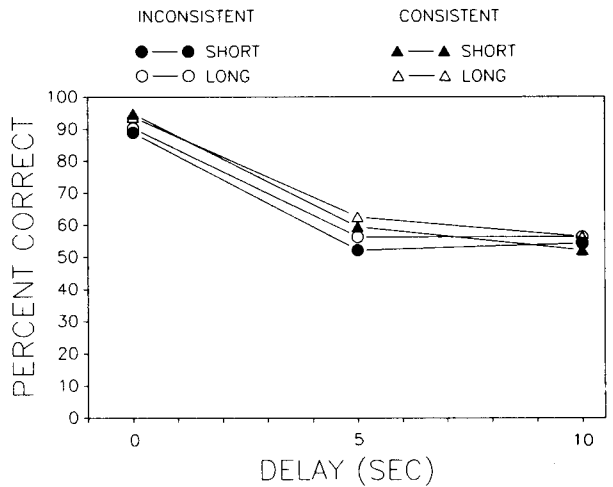

Figure 4. Percentage of correct responses on trials initiated by a short (2-sec) and long (10-sec) sample in each group as a function of delay during the concurrent delay and double-sample test in Experiment 2.

group nor any interactions involving the group factor were significant.

Concurrent Delay and Double-Sample Test

Retention functions on single-sample trials initiated by a short and a long sample in each group are shown in Figure 4. Neither group demonstrated a choose-short effect at the longer delays; in fact, accuracy on long-sample trials was slightly higher than on short-sample trials at both the 5- and 10-sec delays. A group × sample duration × delay ANOVA revealed delay as the only significant term $[F(2,28) = 60.17]$.

The percentage of long choices on the two types of double-sample trials, short-short (S-S) and short-long (S-L), and on the short (S) and long (L) single-sample trials in each group is shown in Figure 5. Both groups demonstrated temporal summation. An ANOVA performed on the percentage of long choices revealed significant main effects of presample duration $[F(1,14) = 21.70]$ and target-sample duration $[F(1,14) = 552.04]$. The interaction between presample duration and target-sample duration was also significant $[F(1,14) = 13.02]$.
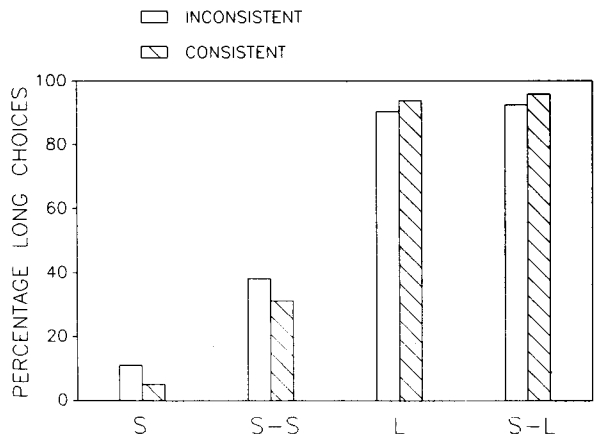

Figure 5. Percentage of choices of the comparison stimulus associated with a long sample as a function of presample duration on the 0-sec delay single-sample trials (L = long, S = short) and the two types of double-sample trials (S-S = short-short, S-L = short-long) in each group during the concurrent delay and double-sample test in Experiment 2.

poral. Moreover, the finding that temporal summation occurred in the absence of a choose-short effect when double-sample and delay-testing trials were presented in the same session provides particularly powerful evidence of a dissociation between these two effects.

GENERAL DISCUSSION

The experiments reported in this article extended the finding that a temporal-summation effect occurs in situations that do not produce the choose-short effect (Santi et al., 1993; Spetch & Grant, 1993). In Experiment 1, one group of pigeons was trained in a many-to-one sample-to-comparison mapping arrangement in which one duration sample and one visual sample were associated with a particular comparison stimulus. Consistent with other published results, a choose-short effect was not obtained during delay testing (Grant & Spetch, 1993; Santi et al., 1993) and a temporal-summation effect was obtained during double-sample testing (Santi et al., 1993). The present research included two additional groups that were trained with either temporal samples only or temporal and nontemporal samples mapped onto different sets of comparison stimuli. Each demonstrated a choose-short effect during delay testing.

The finding that the three groups did not differ during double-sample testing suggests that not only the occurrence but also the magnitude of the temporal-summation effect are independent of whether or not the training procedure produces a choose-short effect during delay testing. Experiment 2 extended the generality of the dissociation of the choose-short and temporal-summation effects by demonstrating the latter, but not the former, following two different many-to-one training procedures in which both sets of samples were temporal.

The present results, in combination with those of Santi et al. (1993) and Spetch and Grant (1993), provide convincing evidence that the temporal-summation and choose-short effects are produced by separate processes. The theoretical view that emerges from this research maintains that temporal summation is a function of processes mediating the perception of duration, whereas the choose-short effect is a function of processes mediating memory for duration (Kraemer & Roper, 1992; Santi et al., 1993; Spetch & Grant, 1993).

The fact that the choose-short effect occurs following training in some procedures (choice matching involving a one-to-one mapping) and not following training in other procedures (successive matching and choice matching involving a many-to-one mapping) suggests that the processes mediating memory for duration are flexible in that the code used to represent duration in working memory varies across procedures (see, e.g., Grant, 1993, and Grant & Spetch, 1993, for further discussion concerning coding of duration in pigeons). In contrast, the fact that the temporal-summation effect has been obtained in all

cases in which it has been sought suggests that the processes mediating duration perception are invariant across the different procedures that have been used to assess memory for duration in pigeons.

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