

Influence of Nonmemorial Factors on Manifestation of Short-Sample Biases in Choice and Successive Matching-to-Duration Tasks With Pigeons

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The effects of procedural modifications of choice and successive matching tasks on retention of event duration (2- and 10-s presentations of light) were examined. In accord with prior results, retention testing revealed that accuracy on short- and long-sample trials declined symmetrically in standard successive matching but asymmetrically (i.e., markedly on long-sample trials, and very little on short-sample trials) in standard choice matching. Moreover, asymmetrical retention functions were also obtained in (a) a modified successive task in which all trials ended in reinforcement and (b) a modified choice task in which the penalty for incorrect responding was substantially reduced. It was concluded that pigeons code duration analogically in both standard choice and successive matching tasks, and that such coding is manifest in asymmetrical retention functions only in the absence of a response bias engendered by the standard successive procedure.

The delayed matching-to-sample (DMTS) task has been used extensively in the analysis of memory for duration in pigeons (see Grant, Spetch, & Kelly, 1997). A typical DMTS duration task involves two samples and two test stimuli. On trials beginning with a "short" sample (e.g., a 2-s house-light), one test stimulus (e.g., red) is designated as positive (and hence, pecking it is reinforced) and the other (e.g., green) is designated as negative (and hence, pecking it does not produce reinforcement). On trials beginning with a "long" sample (e.g., a 10-s house-light), the contingencies are the reverse (in this example, green would be positive and red would be negative).

Memory for sample duration has been assessed using both *choice* and *successive* versions of matching. In the choice version, termination of the duration sample is followed by the simultaneous presentation of the two test stimuli. The pigeon is permitted to make a single choice response, which is reinforced if the positive stimulus was chosen and is not reinforced if the negative stimulus was chosen. In the successive version, termination of the duration sample is followed by presentation of a single test stimulus for a minimum duration (e.g., 5 s). If the test stimulus is positive, the first peck after the minimum duration is reinforced. If the test stimulus is negative, it terminates in nonreinforcement after the minimum duration.

It has recently been discovered that there are some functional differences between the two versions of DMTS duration (Grant & Spetch, 1991; Spetch & Grant, 1993). In the choice version, on trials in which an extended delay follows the short or long sample, pigeons increasingly tend to choose the test stimulus that is correct after a short sample, regardless of which sample had actually occurred on that trial. The empirical result of this tendency is stable and accurate choice performance on trials in which the short sample had occurred, in combination with a precipitous decline in choice accuracy on trials in which the long sample had occurred, as length of the delay is increased. The asymmetry in short- and long-sample retention functions with increasing delay in choice DMTS duration is known as the *choose-short effect* (Spetch, 1987; Spetch & Wilkie, 1982, 1983).

By comparison, when extended-delay trials are presented in the successive version of DMTS duration, birds respond more to a negative test stimulus, regardless of whether a short or a long sample had occurred on that trial (Grant & Spetch, 1991; Spetch & Grant, 1993; Spetch, Grant, & Kelly, 1996). The empirical result is a gradual decline in accurate test-stimulus responding on both short- and long-sample test trials as length of the delay is increased. In other words, the choose-short effect observed in the choice task is not mirrored by a *respond-short effect* in the successive task. Instead, retention functions decline symmetrically on short- and long-sample trials with increasing delay in the successive DMTS duration procedure.

The source of this difference in symmetry of retention functions has recently received theoretical treatment (see Grant et al., 1997). We have argued that the difference reflects the operation of unique working memory codes in the two procedures, that is, a *differential-coding view* (Grant & Spetch, 1991, 1993; Spetch & Grant, 1993; Spetch et al., 1996). Accordingly, in the choice procedure duration samples

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are believed to be retained in working memory as an analogical code. The analogical code of a duration sample is believed to represent the cumulative nature of a temporal stimulus. For example, short and long samples may be coded as the number of periodic elements that accumulate during a 2- and 10-s event, respectively. Thus, an analogical code of the short sample might consist of the few elements that had accumulated over a 2-s event, whereas an analogical code of the long sample might consist of the many elements that had accumulated over a 10-s event.

On a trial with an extended delay, the working-memory code that had been established by the sample on that trial is thought to gradually weaken. With an analogical code, such weakening may be conceptualized as a systematic loss over time of the periodic elements that had accumulated during the sample event, that is, a "subjective shortening" of the coded duration (Spetch, 1987; Spetch & Wilkie, 1982, 1983). Consequently, over the delay the analogical code of a long sample would increasingly correspond to the few elements associated with a short sample and, as a result, choice of the short-associated test stimulus would become increasingly likely. In contrast, the analogical code of a short sample would, with longer delays, continue to correspond more closely to the few elements associated with a short sample than to the many elements associated with a long sample. As a result, choice of the short-associated test stimulus would remain likely.

By contrast, in the successive procedure duration samples are believed to be retained in working memory as a nonanalogical code (Grant & Spetch, 1991; Spetch & Grant, 1993). For example, short and long samples may activate categorical representations, either retrospective (e.g., "short," "long") or prospective (e.g., "peck red," "peck green"). Note that on extended-delay trials, weakening of the categorical codes activated by short and long samples should proceed at the same rate. In particular, the categorical code activated by a long sample should weaken over an extended delay, but the code should not come to increasingly correspond to the categorical code of a short sample. Thus, a delay would permit a gradual loss of accuracy, both on short- and on long-sample trials.

We have speculated about the mechanisms that activate analogical or categorical coding in DMTS duration tasks. Earlier views implicated the importance of evaluative processes (Grant & Spetch, 1991; Spetch & Grant, 1993). Accordingly, tasks that emphasize comparative evaluations (e.g., choose Test Stimulus A vs. choose Test Stimulus B), such as the standard-choice procedure, were believed to activate analogical coding of duration, thereby permitting subjective shortening (and, consequently, a choose- or respond-short effect) over an extended delay. Conversely, tasks that emphasize instructional evaluations (e.g., respond to Test Stimulus A and do not respond to Test Stimulus B), such as the standard successive procedure, were believed to activate categorical coding of duration, thereby precluding subjective shortening (and, consequently, preventing a choose- or respond-short effect) over an extended delay.

An alternate theoretical account implicated a role for inhibitory processes in determining code content in DMTS

duration tasks (Spetch et al., 1996). On this view, tasks that require only momentary inhibition of responding to negative test stimuli (e.g., the standard-choice procedure) were thought to activate analogical coding, thereby permitting subjective shortening and consequent choose- or respond-short effects. Conversely, tasks that require lengthy inhibition of responding to negative test stimuli (e.g., the standard successive procedure) were thought to activate categorical coding, thereby precluding subjective shortening and consequent choose- or respond-short effects.

Consider, however, the possibility that the same coding process prevails in both tasks, and that differences in patterns of retention reflect nonmemorial processes, that is, a *single-coding view*. Indeed, previous research has demonstrated that duration is perceived similarly in the two tasks (Spetch & Grant, 1993). Perhaps, contrary to our earlier views, duration is also coded similarly in working memory. Specifically, analogical coding may prevail in both procedures. However, the typical successive procedure, in which a reinforced behavioral option is not available when the negative test stimulus is encountered, might encourage a "when-in-doubt, peck" response bias (Roper & Zentall, 1993, p. 522) that masks expression of such coding in a respond-short effect.

To elaborate, consider that during training in a successive DMTS duration task there will be occasional trials in which the animal is uncertain about which sample had occurred and, therefore, whether the test stimulus is positive or negative. But because the subject cannot lose reinforcement for responding to a negative test stimulus, a tendency to respond to an uncertain test stimulus receives little punishment (i.e., only wasted effort) if the test stimulus is negative. Moreover, a tendency to respond to an uncertain test stimulus receives considerable reinforcement (i.e., food) if the test stimulus is positive. Hence, in the standard successive task, whenever an uncertain test stimulus is encountered, contingencies are arranged to encourage a "when-in-doubt, peck" response bias.

On an extended-delay trial the animal would likely be uncertain about which sample had occurred. Consequently, the "when-in-doubt, peck" response bias would result in increased responding to negative test stimuli on extended-delay trials, regardless of whether the short or the long sample had occurred on that trial. As a result, evidence of a subjectively shortening code (i.e., a respond-short effect) would be obscured.

This research evaluated the differential-coding and single-coding (incorporating the "when-in-doubt, peck" assumption) accounts of retention asymmetries in DMTS duration. Specifically, by using modified versions of the successive and choice DMTS tasks, we tested the hypothesis that symmetrical retention functions would be found only under procedural conditions that fail to discourage a "when-in-doubt, peck" response bias.

Experiment 1

Experiment 1 used a modified successive DMTS duration task. Specifically, Urcuioli and Zentall's (1990, 1992) sym-

metrically reinforced version of successive matching was adapted to the duration task. As in the standard successive procedure, responding to the positive (or "go") test stimulus was reinforced. Thus, if birds pecked the go test stimulus, they received access to grain. However, in contrast to the standard task, not responding to the negative (or "no-go") test stimulus was also reinforced. Thus, birds had to refrain from pecking the no-go test stimulus for 5 s before they received access to grain. In this way, the penalty for negative test-stimulus responding was increased, because such responding delayed presentation of reinforcement. Note that on trials in which the no-go (negative) test stimulus was presented, there was a reinforced behavioral option, that is, withholding responses.

This procedure should discourage a "when-in-doubt, peck" response bias because indiscriminant pecking delayed presentation of reinforcement on no-go trials. Hence, the single-coding view anticipates a respond-short effect in the modified successive task because evidence of subjective shortening of an analogical code would not be obscured by a "when-in-doubt, peck" response bias. In contrast, the differential-coding view anticipates the absence of a respond-short effect in the modified task because the modified task was equivalent to the standard-choice task in terms of the two procedural features regarded as contributing to nonanalogical coding: Specifically, the procedure emphasized instructional evaluations (respond to Test Stimulus A, do not respond to Test Stimulus B) and involved prolonged inhibition of responding to no-go test stimuli.

The modified successive task was used in the A replications of an ABA design. In the B condition that intervened between the A replications, birds were exposed to the standard successive DMTS task, in which the negative (i.e., former no-go) test stimulus now merely terminated without reinforcement, regardless of the subject's behavior. It was anticipated that a respond-short effect would not occur during testing in the B condition. The critical question was whether in the A condition a respond-short effect would occur (as predicted by the single-coding view) or would not occur (as predicted by the differential-coding view).

Method

Subjects

Between sessions, 4 Silver King pigeons (*Columba livia*) obtained from a local supplier were kept in separate cages in a common colony room. Each bird was maintained at approximately 85% of its free-feeding weight and had continuous access to water and grit in its cage. A 12-hr light-dark schedule (light onset at 7 a.m.) cycled in the colony room. Experimental sessions were limited to 1 hr in duration, and daily sessions began at roughly the same time for each subject. Five to six sessions were given per week. All pigeons had previously served in spatial discrimination experiments, but none had experience in discrimination of duration.

Apparatus

Four operant chambers were used with inner chamber dimensions of 34.0 cm × 30.0 cm × 34.0 cm (Height × Length × Width).

Each chamber had a barred floor base and a panel on one end wall that held two horizontally aligned pecking keys (each 2.5 cm in diameter, spaced 15.8 cm center to center). The bottom edges of the keys were raised 23.0 cm above the floor. Projectors (Industrial Electronics, Inc., Van Nuys, CA) behind the left and right keys were capable of presenting homogeneous fields of red and green onto the key, and a force of at least .25 N applied to the key could be detected as a keypeck response. A 28-V houselamp was attached to the panel 31.0 cm above the floor, and a shield on the lamp directed light toward the ceiling. A rectangular opening in the panel (5.5 cm wide × 5.0 cm high), the bottom edge of which was 9.0 cm above the floor, provided access to a retractable food magazine filled with mixed grain. When the magazine was triggered, the opening was lighted by a recessed and shielded 28-V bulb. The chambers were situated in a darkened experimental room, and they were controlled by a microcomputer located in an adjacent room.

Procedure

Magazine training and autoshaping. Magazine training was provided until pigeons demonstrated reliable eating from the magazine opening on presentation of mixed grain. Next, autoshaping of peck responses to red and green stimuli on the right key was conducted.

First A replication: Modified successive DMTS duration procedure. Each trial began with a duration sample, consisting of either a short (2 s) or a long (10 s) presentation of light on the houselamp. On a given trial, each sample was equally likely, with the restriction that both samples occurred equally often within each session. Immediately on termination of the sample (i.e., 0-s delay), a test stimulus was presented on the right key for a minimum 5-s duration. The color of the test stimulus, red or green, was randomly determined with the restriction that the four possible combinations of sample duration and test-stimulus color occurred with equal frequency within each session. For each subject, one color was designated as a go stimulus if it followed the short sample and a no-go stimulus if it followed the long sample, whereas the reverse designations held for the alternate color. The go/no-go assignments of samples to test stimuli were counterbalanced over subjects. Thus, for 2 subjects, red was a go stimulus if it followed the short sample and no-go stimulus if it followed the long sample, whereas green was go if it followed the long sample and no-go if it followed the short sample. For the remaining two subjects, relationships between sample-test stimulus combinations and go/no-go responding were reversed.

If a go test stimulus occurred after the sample, then the first keypeck to the test stimulus after 5 s elapsed was followed immediately by a 3-s presentation of grain (i.e., a fixed interval [FI], 5-s schedule of reinforcement). Alternatively, if a no-go test stimulus occurred, then the absence of a keypeck for a period of 5 s was required to produce a 3-s presentation of grain (i.e., a differential reinforcement for other behavior [DRO] 5-s schedule of reinforcement). A peck to a no-go test stimulus merely reset the DRO timer. Following the reinforcement period, a 30-s intertrial interval (ITI) intervened before the sample for the following trial. Each session consisted of 48 trials, and sessions were virtually always completed within the 1-hr time limit.

On each trial, peck responses to the test stimulus were summed over the first 5 s of the stimulus and were recorded separately after short and long samples. Furthermore, within each sample type, responses were also separated with respect to go and no-go designations of test stimuli. Two discrimination ratios (DRs), "short-sample" DR and "long-sample" DR, were computed by taking the ratio of all go test-stimulus responses to total (go + no-go) test stimulus responses on all trials with each of the two sample

types. Hence, a DR of 0.50 indicates no discrimination (chance performance) between go and no-go test stimuli for a given sample type, whereas a DR of 1.00 indicates perfect discrimination between go and no-go test stimuli for a given sample type.

For each subject, all go and no-go test-stimulus responses after short and long samples were collapsed over consecutive sessions into blocks of four sessions. The acquisition criterion, which was used in all phases, was met when both short- and long-sample DRs equaled or exceeded 0.80 for two consecutive blocks. On meeting this criterion, subjects received three separate phases of extended-delay testing, with each phase consisting of four sessions. Test sessions were identical to those of training in all aspects but the following one: The 0-s baseline delay occurred on only 50% of trials, whereas one extended delay occurred on 25% of trials, and a second extended delay occurred on the remaining 25% of trials. Test Phase 1 used 5- and 10-s extended delays, whereas Test Phases 2 and 3 used 10- and 20-s extended delays. The delay that occurred on a given trial was determined randomly, with the restriction that the overall proportion of delay trials within a session conformed to this 50:25:25 ratio. Trials at each delay were counterbalanced with respect to sample type and test-stimulus color.

In Test Phases 1 and 2, sessions were given consecutively: In Phase 3, "recovery" sessions, during which conditions were identical to those of previous 0-s delay training, were given between adjacent test sessions. Recovery sessions were also given between phases of extended-delay testing. Recovery between phases was considered complete when both short- and long-sample DRs equaled or exceeded 0.80 for two consecutive sessions in which all 48 trials had been completed in both sessions. Recovery during Test Phase 3 was considered complete when both DRs equaled or exceeded 0.80 for one session in which all 48 trials had been completed. Mean number of recovery sessions between test phases was 3.4 (range = 2 to 8), and mean number of recovery sessions between adjacent test sessions of Test Phase 3 was 1.3 (range = 1 to 5).

B condition: Standard successive DMTS duration procedure. Initial training sessions were identical in all aspects to those of training in the first A replication, except that the DRO 5-s schedule of reinforcement was replaced by an extinction 5-s schedule. Thus, responding or not responding to a no-go test stimulus had no effect, and the stimulus merely terminated after 5 s.

After meeting the acquisition criterion, subjects received three phases of extended-delay testing that were identical in all aspects to those of the first A replication, except that the DRO 5-s schedule of reinforcement to a no-go test stimulus was replaced by the extinction 5-s schedule. Mean number of recovery sessions between test phases was 5.1 (range = 2 to 8), and mean number of recovery sessions between adjacent test sessions of Test Phase 3 was 2.3 (range = 1 to 5). Following Test Phase 3, subjects were given recovery training until performance had recovered for two consecutive sessions in which all 48 trials had been completed in both sessions. Mean number of recovery sessions was 2.3 (range = 2 to 3).

Second A replication: Modified successive DMTS duration procedure. Training was identical in all aspects to that of the first A replication. On acquisition, subjects received three phases of extended-delay testing that were identical in all aspects to those of the first A replication. Mean number of recovery sessions between test phases was 2.9 (range = 2 to 6), and mean number of recovery sessions between adjacent test sessions of Test Phase 3 was 1.7 (range = 1 to 5). All analyses to follow used $\alpha = .05$ to define the region for rejection of the null hypothesis.

Results

First A Replication: Modified Successive DMTS Duration Procedure

Subjects met the acquisition criterion in a mean of 11 four-session blocks (range = 6 to 18) and mean short- and long-sample DRs by the end of acquisition were 0.84 (range = .80 to .92) and 0.86 (range = .82 to .89), respectively. Data plotted in the upper panel of Figure 1 indicate the presence of respond-short effects in all three delay test phases. Short- and long-sample DR data from each phase were submitted to repeated-measures analyses of variance

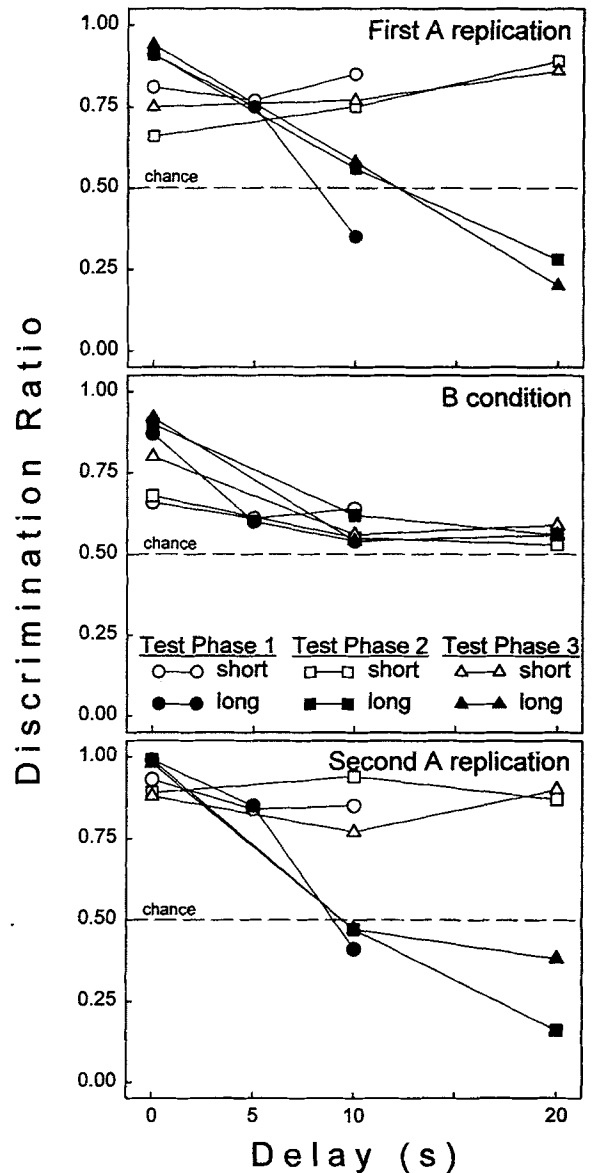


Figure 1. Discrimination ratio after samples of short (2 s) and long (10 s) durations of houselight as a function of delay duration in the first A replication (upper panel), the B condition (middle panel), and the second A replication (lower panel).

(ANOVAs) with sample type (short and long) and delay (0, 5, and 10; or 0, 10, and 20) as within-subjects factors. The delay term was significant in all three phases of testing, respective $F_s(2, 6) = 12.95, 19.89, \text{ and } 12.73$, whereas the sample term was significant in Phases 2 and 3, respective $F_s(1, 3) = 19.97 \text{ and } 16.65$. Most important, the Sample \times Delay interaction was significant in all three phases of testing, respective $F_s(2, 6) = 17.02, 50.90, \text{ and } 39.99$.

To analyze the interaction terms, we conducted Newman-Keuls multiple comparisons on short- versus long-sample DR at each of the three delays in each of the three test phases. There was a significant tendency toward higher short- than long-sample DR at the 10-s delay of Delay Tests 1 and 2, and at the 20-s delay of Delay Tests 2 and 3. Higher short- than long-sample DR on extended-delay tests confirms the presence of the respond-short effect in each of the three phases of delay testing. The only remaining significant comparison was a tendency toward higher long- than short-sample DR at the 0-s delay of Test Phase 2.

B Condition: Standard Successive DMTS Duration Procedure

Subjects met the acquisition criterion in a mean of 9.7 blocks (range = 4 to 18), and mean short- and long-sample DRs by the end of acquisition were 0.87 (range = .80 to .95) and 0.87 (range = .82 to .95), respectively. Data plotted in the middle panel of Figure 1 indicate absence of respond-short effects in each of the three delay test phases. A series of ANOVAs, identical to the first A replication, returned a significant delay term in each test phase, respective $F_s(2, 6) = 11.49, 38.74, \text{ and } 75.30$, but the Sample \times Delay interaction was significant only in the first test phase, $F(2, 6) = 22.18$.

Exploration of the interaction term for the first test phase was conducted in identical fashion to the first A replication, and it showed only a significant tendency toward higher long- than short-sample DR at the 0-s delay. Thus, a significant respond-short effect did not appear in any of the three phases of delay testing.

Second A Replication: Modified Successive DMTS Duration Procedure

All subjects met the acquisition criterion in the minimum of two blocks and mean short- and long-sample DRs by the end of acquisition were 0.94 (range = .88 to .98) and 0.98 (range = .94 to 1.00), respectively. Data plotted in the lower panel of Figure 1 indicate the return of a respond-short effect in each of the three delay test phases. A series of ANOVAs, identical to the first A replication, returned a significant delay term in all three phases, respective $F_s(2, 6) = 10.74, 26.87, \text{ and } 31.05$, whereas the sample term was significant only in Phases 2 and 3, respective $F_s(1, 3) = 104.18 \text{ and } 41.28$. Most important, the Sample \times Delay interaction was significant in all three phases of testing, respective $F_s(2, 6) = 27.47, 52.22, \text{ and } 24.90$.

Exploration of these interaction terms, conducted as in the first A replication, showed a significant tendency toward higher short- than long-sample DR at the 10-s delay of all

three test phases and at the 20-s delay of Test Phases 2 and 3. Higher short- than long-sample DR on extended-delay tests confirms the return of the respond-short effect in each of the three phases of delay testing.

Finally, a direct comparison was made between the A replications and the B condition in the third delay test, in which the delays were 0, 10, and 20 s. This was accomplished by conducting an initial Sample \times Delay \times Replications ANOVA on data from the two A replications. Neither the main effect of replications nor any interactions involving the replications factor were significant, which justified collapsing data across the two A replications. A Sample \times Delay \times Conditions ANOVA was then conducted comparing performance in the A and B conditions in the third delay test. That analysis revealed a significant three-way interaction, $F(2, 6) = 64.20$, confirming the statistical reliability of the stronger respond-short effect in the A condition than in the B condition.

Figure 2 shows rates of responding to go (positive) and no-go (negative) test stimuli for each of the two samples as a function of delay for the second phase of delay testing (response-rate patterns in the other two test phases were

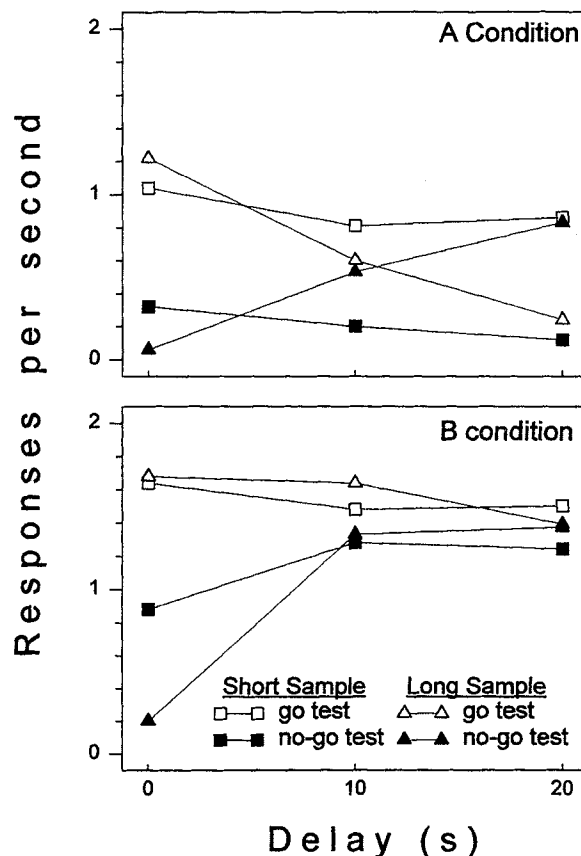


Figure 2. Responses per second to go and no-go test stimuli after samples of short (2 s) and long (10 s) durations of houselight as a function of delay duration in the second test phase of the A condition (upper panel) and the B condition. The data for the A condition are collapsed across the two replications.

highly similar). The data are collapsed across the two A replications because a Sample \times Test (go and no-go) \times Delay \times Replications ANOVA revealed that neither the main effect of replications nor any interactions involving the replications factor were significant. Data at the 0-s delay revealed a similar pattern in each condition, whereas those at the 20-s delay revealed a very different pattern in the two conditions. Specifically, at the 0-s delay, response rates in both conditions were high on go trials and low on no-go trials for both samples. A Trial Type (short go, short no-go, long go, and long no-go) \times Conditions ANOVA performed on data from the 0-s delay confirmed the lack of between-conditions differences in the pattern of responding, in that the Conditions \times Trial Type interaction was not significant, $F(3, 9) = 2.45$. The significant effect of trial type, $F(3, 9) = 11.03$, was further analyzed by conducting Newman-Keuls multiple comparisons. These comparisons revealed that response rates were higher on short and long go trials than on short and long no-go trials.

At the longer delays, however, there were marked between-conditions differences in the pattern of responding. Consider first data from the A condition (upper panel), in which as delay lengthened on short-sample trials response rate remained high to go test stimuli (open squares) and low to no-go stimuli (filled squares). Hence, at longer delays, as at shorter delays, pigeons responded on short-sample trials as if the sample had indeed been short (i.e., correctly) regardless of whether the go or no-go test stimulus was presented. A very different pattern emerged on long-sample trials. Response rate was high to go test stimuli (open triangles) and low to no-go test stimuli (filled triangles) at the 0-s delay, but converged at the 10-s delay. At the 20-s delay, response rates reversed: Response rate was higher to no-go than to go test stimuli. Hence, at the longest delay, pigeons responded on long-sample trials as if the sample had been short (i.e., incorrectly) both when the go and the no-go test stimulus was presented.

Inspection of the lower panel in Figure 2 reveals a contrasting pattern of response-rate changes as a function of delay in the B condition. Response rates to positive test stimuli (open symbols) changed very little as a function of delay, remaining high and steady. In contrast, response rates to negative test stimuli (filled symbols) were low at the 0-s delay and increased substantially at the 10- and 20-s delays. Indeed, at the longer delays, pigeons pecked negative test stimuli almost as rapidly as they pecked positive test stimuli. Importantly, this pattern prevailed on both short- and long-sample trials. Hence, there is no evidence that, at longer delays, pigeons treated long samples as if they had been short, as was the case in the A replications. Instead, on both short- and long-sample trials, pigeons tended to respond rapidly and indiscriminantly to both positive and negative test stimuli.

A Trial Type (short go, short no-go, long go, and long no-go) \times Conditions ANOVA performed on data from the 20-s delay confirmed the presence of between-conditions differences in pattern of responding in that the Condition \times Trial Type interaction was significant, $F(3, 9) = 8.52$. To further analyze this interaction, we performed separate

one-way ANOVAs on the 20-s data from each condition. In the A condition, the effect of trial type was significant, $F(3, 9) = 7.81$, and Newman-Keuls comparisons revealed that responding was higher on short go and long no-go trials than on short no-go and long go trials. In the B condition, in contrast, the effect of trial type was not significant, $F(3, 9) = 1.81$, revealing that pigeons pecked test stimuli indiscriminately at the 20-s delay in the B condition.

Overall, results demonstrate that in the successive DMTS duration task, increasing the penalty for negative (i.e., no-go) test-stimulus responding and providing a reinforced behavioral option when the test stimulus is negative (i.e., first A replication) was sufficient to produce a respond-short effect. Moreover, removal of these procedural features (i.e., B condition) resulted in elimination of the effect, and subsequent restoration of the modifications (i.e., second A replication) resulted in its reappearance.

Discussion

The occurrence of a respond-short effect in the symmetrically reinforced version of successive DMTS duration (A replications) is inconsistent with a differential-coding view of retention asymmetries in DMTS duration. Specifically, because the procedure in the A replications emphasized instructional evaluations and required prolonged inhibition of responding to no-go test stimuli, categorical coding would be anticipated, thereby precluding emergence of a respond-short effect during testing with extended delays.

In contrast, the results are in accord with a single-coding view that incorporates a "when-in-doubt, peck" assumption. On this view, pigeons coded the duration samples analogically in both the A replications and B condition. Because training in the B condition encouraged a "when-in-doubt, peck" response bias, evidence of subjective shortening of an analogical code was obscured. However, because training in the A condition discouraged such a response bias, evidence of subjective shortening of an analogical code was not obscured. Response-rate data provided clear evidence of a "when-in-doubt, peck" response bias in the B condition and its absence in the A replications.

Experiment 2

The results of Experiment 1 were interpreted as implicating a "when-in-doubt, peck" response bias as a critical determinant of whether choose- or respond-short effects are obtained. Specifically, it was maintained that a "when-in-doubt, peck" response bias emerges in procedures that fail to discourage that response bias (i.e., typical successive matching) and, moreover, that such a response bias obscures evidence of a subjective-shortening process.

The standard successive task differs from both the symmetrically reinforced version of the successive task and the standard-choice task in two ways, either of which might be critical for failing to discourage a "when-in-doubt, peck" response bias. First, in the standard successive task, incorrect responses (i.e., pecks to a negative test stimulus) incur no penalty in terms of missed or delayed reinforcement.

Instead, the only penalty associated with such indiscriminate responding is wasted effort. By contrast, in the standard-choice task, incorrect choices lead to a substantial delay of reinforcement (i.e., reinforcement does not become available again until after the timeout, the ITI, and the next trial period). Similarly, in the symmetrically reinforced successive task, each peck to the no-go test stimulus delays reinforcement by 5 s. Therefore, the presence of a substantial penalty for incorrect responses may be a critical factor in discouraging indiscriminate responding at long delays.

A second factor that could be important is that negative trials in the standard successive task provide no behavioral option that can lead to reinforcement. Thus, when subjects are in doubt about which sample had occurred, they may peck because there is no other reinforced behavioral option available. By contrast, a reinforced behavioral option is always available in the choice task (i.e., pecking the correct key) and in the symmetrically reinforced successive task (i.e., pecking on go trials and withholding pecking on no-go trials). The presence of a reinforced behavioral option may discourage indiscriminate responding and encourage subjects to respond according to memory of the sample even when in doubt (i.e., after a substantial delay).

Experiment 2 evaluated whether presence of a reinforced behavioral option by itself (i.e., in the absence of a substantial penalty for incorrect pecks) is sufficient to discourage indiscriminate responding at long delays. To this end, we initially trained and tested naive birds in a choice procedure that was modified to minimize the penalty for incorrect responses, yet left available a reinforced behavioral option on all trials. This was accomplished by making incorrect choices ineffective, such that the test stimuli persisted until a correct choice occurred, even if the initial choice was incorrect. Once a correct choice occurred, both test stimuli terminated and reinforcement was presented. Thus, in this modified choice task (A condition), the penalty for responding to the incorrect test stimulus was substantially reduced relative to the standard-choice task. In particular, reinforcement was never lost and was only slightly delayed (i.e., by the time required to switch from the incorrect to the correct test stimulus, typically less than 1 s) when a response occurred to an incorrect test stimulus.

In the B condition that intervened between the A replications, birds were exposed to the standard-choice DMTS duration task, in which choice of the incorrect test stimulus simply terminated the trial in nonreinforcement (followed by the ITI). Hence, a substantial penalty for indiscriminate responding was imposed (i.e., reinforcement omission on the current trial, followed by an interval averaging 39 s [3-s timeout + 30-s ITI + sample duration, $M = 6$ s] before the next opportunity to obtain reinforcement). It was anticipated that a choose-short effect would occur during testing in the B condition (standard-choice procedure). The question of primary interest was whether a choose-short effect would also occur in the A condition. If so, data from the A and B conditions could be compared to determine whether magnitude of the penalty for incorrect responding plays an important (as opposed to critical) role in generating the

choose-short effect. It should be noted that both conditions provide a reinforced behavioral option on all trials. Hence, to the extent that this factor is sufficient to discourage indiscriminate responding at long delays, a choose-short effect would be anticipated in both conditions.

Method

Subjects

Six naive Silver King pigeons (*Columba livia*), between 6 months and 2 years of age were obtained from a local supplier. Birds were maintained as in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

Magazine training and autoshaping. Magazine training and autoshaping were the same as in Experiment 1.

First A replication: Modified choice DMTS duration procedure.

Parameters and procedures were identical to Experiment 1, with the following exceptions. In the present task, immediately following the sample on each trial, both red and green test stimuli were presented, one on the left key and the other on the right. The spatial array of test stimuli was randomly determined, with the restriction that the two left-right combinations were counterbalanced within the sample-type factor. One color was designated correct if it followed the short sample and incorrect if it followed the long sample, and the reverse designations held for the alternate color. For 3 birds, red was correct if it followed the short sample and incorrect if it followed the long sample, whereas green was correct if it followed the long sample and incorrect if it followed the short sample. For the remaining 3 pigeons, these sample-to-test stimulus relationships were reversed.

A single peck to the correct test stimulus terminated both test stimuli and resulted in 3-s grain reinforcement. All pecks to the incorrect test stimulus were without consequence. Test stimuli simply persisted on each trial until the correct test stimulus was chosen. Following reinforcement, the ITI occurred, after which the next trial was presented.

Within each session for each sample type, only the first test stimulus to be chosen was used to calculate accuracy. The total number of first-choice correct responses was divided by the total number of trials to produce a first-choice percentage correct measure. Both short- and long-sample percentage correct scores were computed in each session. Thus, 50% correct indicates chance responding between correct and incorrect test stimuli for a given sample type, whereas 100% correct indicates perfect discrimination between correct and incorrect test stimuli for a given sample type. Subjects were provided a minimum of 20 sessions of training. The acquisition criterion was met when percentage correct collapsed over sample type, equaled or exceeded 80% for five consecutive sessions (including sessions 16 through 20).

On acquisition, subjects received two separate phases of extended-delay testing, with each phase consisting of eight consecutive test sessions. Test sessions were identical to those of training in all aspects but the following: The 0-s baseline delay occurred on only 50% of trials, whereas one extended delay occurred on 25% of trials, and a second extended delay occurred on the remaining 25%

of trials. Test Phase 1 used 5- and 10-s extended delays, whereas Test Phase 2 used 10- and 20-s extended delays. The delay that occurred on a given trial was determined randomly, with the restriction that the overall proportion of delay trials within a session conformed to this 50:25:25 ratio. Trials at each delay were counterbalanced with respect to sample type and side-key location of the correct test stimulus. As in training, percentage correct scores were recorded separately for short- and long-sample trials. In addition, percentage correct scores were separated according to which of the three delays had preceded test-stimulus presentation.

Recovery sessions, during which conditions were identical to those of previous 0-s delay training, were given between the two test phases. Recovery was considered complete when percentage correct collapsed over sample type, equaled or exceeded 80% for two consecutive sessions. Subjects met this criterion in a mean of 3.3 sessions (range = 2 to 9).

B condition: Standard choice DMTS duration procedure. Initial training sessions were identical in all aspects to those of training in the first A replication, except that the test stimuli always terminated immediately on the first choice response, regardless of which test stimulus had been chosen. Reinforcement was provided if the correct test stimulus had been chosen, whereas reinforcement was omitted and a 3-s timeout occurred if the incorrect test stimulus had been chosen, after which the ITI was presented. The acquisition criterion was met when (a) percentage correct collapsed over sample type equaled or exceeded 80% for two consecutive sessions and (b) the subject had had at least four sessions of training.

After acquisition, subjects received two phases of extended-delay testing that were identical in all aspects to those of the first A replication, except that the test stimuli terminated immediately on the first choice response, in reinforcement if the correct test stimulus was chosen and in nonreinforcement if the incorrect test stimulus was chosen. All subjects required only the minimum two recovery sessions between the test phases.

Second A replication: Modified choice DMTS duration procedure. Training was identical in all aspects to that of the first A replication. The acquisition criterion was met when (a) percentage correct collapsed over sample type equaled or exceeded 80% for two consecutive sessions and (b) the subject had had at least four sessions of training.

On acquisition, subjects received one phase of extended-delay testing that was identical in all aspects to the second extended-delay test phase of the first A replication. All analyses to follow used $\alpha = .05$ to define the critical region for rejection of the null hypothesis.

Results

First A Replication: Modified Choice DMTS Duration Procedure

Subjects met the acquisition criterion in a mean of 30.5 sessions (range = 20 to 79). Data plotted in the upper panel of Figure 3 indicate occurrence of a choose-short effect, particularly in the second test phase. Short- and long-sample percentage correct from each phase were submitted to repeated-measures ANOVAs with sample type and delay as within-subjects factors. The delay term was significant in both phases of testing, respective $F_s(2, 10) = 39.65$ and 45.97 , whereas the sample term was not significant in either phase, $F_s < 3.63$. Most important, the Sample \times Delay interaction was significant in both phases of testing, respective $F_s(2, 10) = 7.96$ and 13.50 .

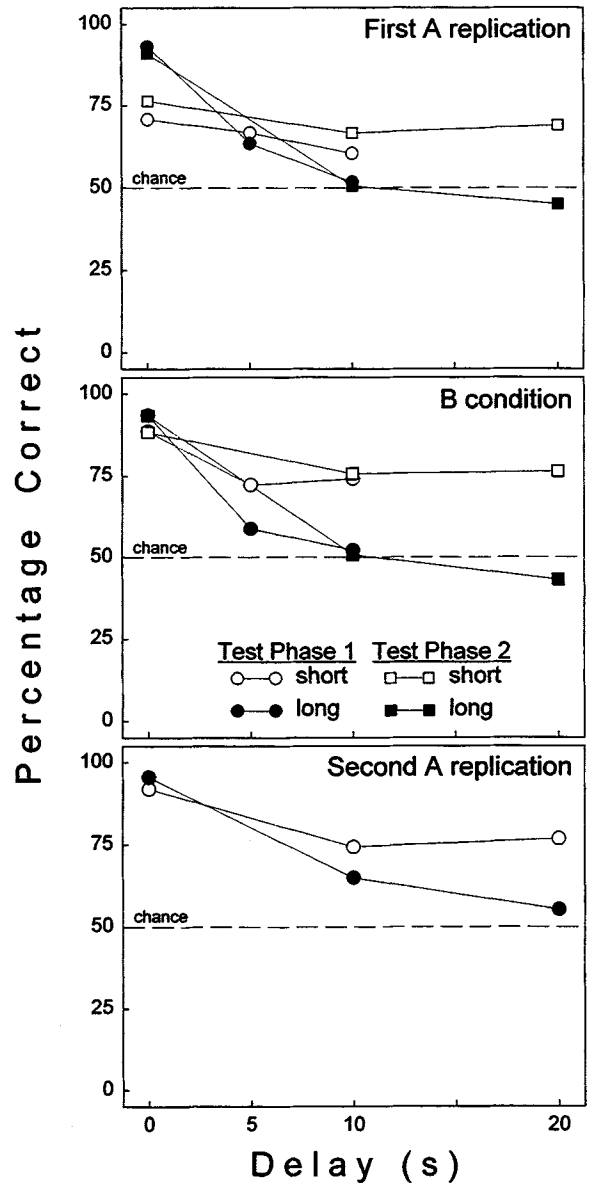


Figure 3. Percentage correct after samples of short (2 s) and long (10 s) durations of houselight as a function of delay duration in the first A replication (upper panel), the B condition (middle panel), and the second A replication (lower panel).

To analyze the interaction terms, we conducted Newman-Keuls multiple comparisons on short- versus long-sample percentage correct at each of the three delays in each of the two test phases. In the first test phase, the only significant comparison was higher long- than short-sample percentage correct at the 0-s delay. However, in the second test phase, short-sample percentage correct was significantly higher than long-sample percentage correct at both the 10- and 20-s delays. Higher short- than long-sample percentage correct on extended-delay tests confirms the presence of the choose-short effect in the second phase of testing.

B Condition: Standard Choice DMTS Duration Procedure

All subjects met the acquisition criterion in the minimum four sessions. Data plotted in the middle panel of Figure 3 indicate a choose-short effect in both test phases. A pair of ANOVAs, identical to the first A replication, returned a significant delay term in Test Phases 1 and 2, respective $F_s(2, 10) = 31.45$ and 78.55 , as well as a significant sample term in both tests, respective $F_s(1, 5) = 11.57$ and 6.85 . In addition, the Sample \times Delay interaction was significant in both test phases, respective $F_s(2, 10) = 12.82$ and 10.23 .

Exploration of the interaction terms was conducted in identical fashion to the first A replication, and showed a significant tendency toward higher short- than long-sample percentage correct at the 5- and 10-s delays of Test 1, and at the 10- and 20-s delays of Test 2. Higher short- than long-sample percentage correct on extended-delay tests confirms the presence of the choose-short effect in each of the two phases of testing.

Second A Replication: Modified Choice DMTS Duration Procedure

All subjects met the acquisition criterion in the minimum four sessions. Data plotted in the lower panel of Figure 3 again indicate a choose-short effect. An ANOVA, identical to the second ANOVA of the first A replication, returned significant terms for delay, $F(2, 10) = 18.76$, and sample, $F(1, 5) = 19.18$. As before, the Sample \times Delay interaction was significant, $F(2, 10) = 5.87$.

Exploration of this interaction term, conducted as in the first A replication, showed a significant tendency toward higher short- than long-sample percentage correct at the 20-s delay, thereby confirming the presence of the choose-short effect during delay testing.

Finally, a direct comparison was made between the A and B conditions in the delay test in which the delays were 0, 10, and 20 s. This was accomplished by conducting an initial Sample \times Delay \times Replications ANOVA on data from the two A replications. Neither the main effect of replications nor any interactions involving the replications factor were significant, which justified collapsing data across the two A replications. A Sample \times Delay \times Conditions ANOVA was then conducted comparing performance in the A and B conditions in the 0-, 10-, and 20-s delay test. That analysis revealed a nonsignificant three-way interaction, $F < 1$, indicating that the magnitude of the choose-short effect was statistically equivalent in A and B conditions.

In general, results demonstrate that in the choice DMTS duration task, decreasing the penalty for negative test-stimulus responding did not eliminate the choose-short effect. Although the effect was not statistically significant during the first test phase with the modified choice task, it was significant during the second test phase, which entailed longer delays. Moreover, a significant choose-short effect appeared again during the second replication with the

modified procedure. In addition, although the choose-short effect appeared to be slightly weaker in the modified procedure than in the standard-choice task, this difference was not statistically significant. Thus, substantially decreasing the penalty for responding to the incorrect test stimulus did not preclude, nor even significantly alter, the choose-short effect.

Discussion

The finding of primary significance was that a choose-short effect was obtained in naive pigeons trained and tested in Condition A in which responding to the incorrect choice stimulus had no programmed consequences. This result is clearly inconsistent with the possibility that imposing a substantial penalty for indiscriminant responding is a necessary condition for allowing choose- or respond-short effects to emerge. It suggests instead that the availability of a reinforced behavioral option is sufficient to discourage a strategy of responding indiscriminately at long delays.

Of secondary importance is the finding that the magnitude of the choose-short effect was not markedly affected by the severity of the penalty for indiscriminant responding. In Condition A, that penalty was minimal (i.e., the time taken to move to and peck the correct choice stimulus), whereas in Condition B it was substantial (i.e., reinforcement omission on the current trial, followed by an interval of approximately 40 s before the next opportunity to obtain reinforcement). In spite of the marked difference in penalty for indiscriminant responding in the two conditions, there was little evidence of a difference in the magnitude of the choose-short effect. Hence, it would appear that the magnitude of the penalty for indiscriminant responding per se has little, if any, effect on the magnitude of retention asymmetries in DMTS duration tasks.

General Discussion

In the two A replications of Experiment 1, pigeons were trained and tested in a symmetrically reinforced version of successive DMTS duration, in which each response to a negative (no-go) test stimulus postponed reinforcement for 5 s. Because that procedure strongly discouraged a "when-in-doubt, peck" response bias, the single-coding account of retention asymmetries in DMTS duration tasks predicts a robust respond-short effect. In contrast, the differential-coding account predicts the absence of a respond-short effect in the symmetrically reinforced successive DMTS duration task. This is the case because that task incorporated procedural features thought important to categorical coding: Specifically, prolonged inhibition of responding to test stimuli was required, and the procedure emphasized instructional evaluations. In accord with the predictions of the single-coding account, and contrary to the predictions of the differential-coding account, a robust respond-short effect did occur in the symmetrically reinforced version of successive DMTS duration.

The notion that a "when-in-doubt, peck" response bias operated in the B condition, but not in the A condition, was directly supported by response-rate data. At extended delays in the B condition, response rate to negative test stimuli was elevated markedly and was approximately equivalent on short- and long-sample trials. Moreover, response rate to positive test stimuli remained high and approximately constant at extended delays on short- and long-sample trials. At the longest delay (i.e., 20 s), the samples failed to exert strong control over test responding and, instead, pigeons pecked at a high rate to all test stimuli, a manifestation of the "when-in-doubt, peck" response bias. At the 20-s delay in the A condition, in contrast, pigeons did not respond at a high rate to all test stimuli. Instead, on both short- and long-sample trials, response rate was high to the test stimulus associated with the FI schedule on short-sample trials (and, hence, associated with the DRO schedule on long-sample trials) and was low to the test stimulus associated with the DRO schedule on short-sample trials (and, hence, associated with the FI schedule on long-sample trials), a manifestation of the choose-short effect.

Experiment 2 examined whether a substantial penalty for incorrect responding is a necessary condition for discouraging the "when-in-doubt, peck" strategy. To this end, pigeons were trained and tested in a modified choice procedure in which a response to an incorrect choice stimulus merely delayed reinforcement briefly (i.e., by the time taken to move to and peck the correct choice stimulus). Although the penalty for incorrect responding was minimal, this procedure, like both the standard-choice task and the symmetrically reinforced successive task, provided a reinforced behavioral option on all trials. The finding that a choose-short effect still appeared despite the substantially reduced penalty for incorrect responses, suggests that the availability of a reinforced behavioral option is a sufficient condition to discourage indiscriminate responding at long delays.

In our view, the single-coding account, incorporating the "when-in-doubt, peck" assumption, can explain all instances in which symmetrical and asymmetrical retention functions have emerged in duration tasks studied by Grant and Spetch (1991), Spetch et al. (1996), and those in this article. Moreover, we believe that such an account can also explain differences in transfer when pigeons are switched from choice to successive procedures and vice versa (Grant & Spetch, 1991, Experiment 2). In that experiment, pigeons were trained initially on either a choice or successive DMTS duration task. Subsequently, pigeons were transferred to the alternate procedure in which the relationship between sample duration and positive and negative test stimuli remained the same. Pigeons transferred from successive to choice DMTS showed robust positive transfer; accuracy was 78% correct on the first transfer session and was asymptotic (greater than 90% correct) by the third session. In contrast, those transferred from choice to successive DMTS showed no evidence of positive transfer; DR was .51 in the first transfer session and acquisition proceeded more slowly than in naive animals.

Grant and Spetch (1991) viewed transfer effects as an index of the applicability of the codes adopted in the first

task to the unique procedures imposed by the second task. The single-coding account, however, offers a different interpretation of transfer effects. On this account, transfer in DMTS duration reflects the extent to which the behavioral pattern (as opposed to coding strategy) of one task is applicable to the second task. Hence, positive transfer from successive to choice DMTS duration reflects the compatibility of the behavioral pattern learned in the successive task (i.e., if positive, then peck; if negative, then do not peck) and that required in the choice task. Moreover, the lack of positive transfer from choice to successive duration DMTS reflects incompatibility of the behavioral strategy learned in the choice task (i.e., if negative, then switch to other key; if positive, then peck once) and that required in the successive task (prolonged inhibition of responding to negative test stimuli, and prolonged responding to positive test stimuli). Notice that the behavioral strategy acquired in the successive task should produce highly accurate (and hence reinforced) responses from the onset of transfer to the choice task. In contrast, the behavioral strategy acquired in the choice task is unlikely to produce accurate performance immediately, resulting in the need to learn the behavioral strategy appropriate to successive matching. It may be noted that the present account anticipates similar patterns of transfer (i.e., strong positive transfer from successive to choice and little positive transfer from choice to successive) regardless of the type of samples used.

Finally, it may be argued that one of Grant and Spetch's (1991) findings is inconsistent with the single-coding account. Specifically, they found that pigeons failed to show a choose-short effect in choice DMTS duration after having been trained in successive DMTS duration. It should be noted, however, that those pigeons (a) should have acquired a "when-in-doubt, peck" response bias during initial training in the successive procedure and (b) rarely made errors in the choice task. Therefore, the "when-in-doubt, peck" response bias may have persisted in the choice task, because the frequency of nonreinforced guessing during training trials on the choice task was too low to result in extinction of that response bias. Hence, on extended-delay trials (i.e., under conditions of uncertainty), the "when-in-doubt, peck" response bias would have been invoked, and evidence of a subjectively shortening analogical code (i.e., the choose-short effect) would have been obscured.

In conclusion, this study discourages a differential-coding view of performance in choice and successive DMTS duration tasks. Instead, data are more supportive of a single-coding account, in which analogical coding is assumed to occur in standard and modified successive DMTS duration tasks that, previously, were believed to produce categorical coding. On this view, absence of choose- or respond-short effects is attributed to the operation of a "when-in-doubt, peck" response tendency. Nevertheless, this conclusion does not deny the possibility that, under certain conditions, such as many-to-one sample-to-test stimulus mapping arrangements, pigeons can code sample duration nonanalogically in DMTS duration (e.g., Fetterman, 1995; Grant & Spetch, 1993; Santi, Bridson, & Ducharme, 1993).

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