JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1996, 65, 81–92 NUMBER 1 (JANUARY)

DETECTING A NONEVENT: DELAYED PRESENCE-VERSUS-ABSENCE DISCRIMINATION IN PIGEONS

DEIRDRA H. DOUGHERTY AND JOHN T. WIXTED

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Eight pigeons were trained on a delayed presence-versus-absence discrimination paradigm in which a sample stimulus was presented on some trials but not on others. If a sample was presented, then a response to one choice key produced food. If no sample was presented, a response to the other choice key produced food. The basic finding was that performance remained constant and well above 50% correct on no-sample trials as the retention interval increased, whereas performance dropped precipitously (to below 50% correct) on sample trials. In the second phase of the experiment, all of the trials were no-sample trials, and reinforcers were delivered probabilistically for one group of pigeons and according to time-based schedules for the other group. The exact reinforcement probabilities used in Phase 2 were those calculated to be in effect on no-sample trials in Phase 1 (according to a discrete-state model of performance). Subjects did not show exclusive preference for the richer alternative on no-sample trials in the first phase, but those in the probabilistic group developed near-exclusive preference for the richer alternative during the second phase. These data are inconsistent with the predictions of the discrete-state model, but are easily accommodated by an account based on signal detection theory, which also can be applied effectively to discrimination of event duration and the "subjective shortening" effect.

Key words: memory, presence-versus-absence discrimination, delayed matching to sample, signal detection theory, timing, key peck, pigeons

The delayed matching-to-sample (DMTS) paradigm has been used extensively to study memory in pigeons. In this procedure, a pigeon is trained to report which of two or more stimuli was previously presented. Typically, one stimulus (the sample) is briefly presented on the center key and then, after a retention interval, choice stimuli are presented on the two side keys. If the pigeon chooses the stimulus that matches the previously presented sample, a reinforcer is delivered.

We used a variant of the standard DMTS paradigm to investigate the pigeon's ability to discriminate whether or not an event had occurred earlier in the trial. Specifically, on sample trials, a blue stimulus was presented on the center key and, after a retention interval, a response on the red choice key was reinforced. On no-sample trials, the choice keys were lit without a stimulus first appearing on the center key, and on these trials a response to the green choice key was reinforced.

Grant (1991) and Wixted (1993) both used this procedure to study memory for the presence or absence of keylights. Several other researchers used a similar procedure in which memory for the presence or absence of food was tested (Colwill, 1984; Sherburne & Zentall, 1993; Wilson & Boakes, 1985). In the latter studies, responding to one choice stimulus was reinforced following a brief presentation of food, whereas responding to the other choice stimulus was reinforced if food had not been presented. The pattern of results that emerged from all of these studies is that performance on the no-sample (or no-food) trials is accurate and does not change as a function of retention interval following the nonevent, whereas performance on sample trials is nearly perfect at short retention intervals and drops below 50% correct at longer retention intervals. This pattern of results emerges whether or not the nonevent is signaled (e.g., by the illumination of an empty hopper).

Colwill (1984), Grant (1991), and Wilson and Boakes (1985) suggested that the lack of decrement in performance as a function of retention interval on no-sample trials is due to the asymmetrical coding of the sample stimuli. According to this account, the bird's default response strategy is to choose the no-sample alternative most of the time. This default strategy is overridden only if a memory

---

This research was supported by Grant IBN-9122395 from the National Science Foundation.

Address correspondence to John T. Wixted, Department of Psychology, 0109, University of California, San Diego, La Jolla, California 92093-0109.

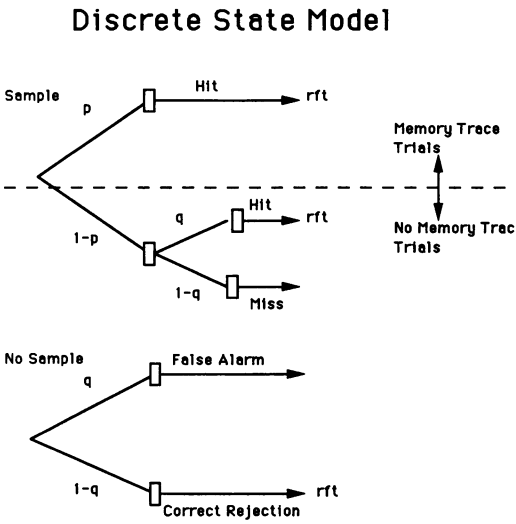

Fig. 1. A graphical representation of the discrete-state model. Both sample and no-sample trials are described, and the dotted line divides memory-trace trials from no-memory-trace trials. The symbol *p* represents the proportion of sample trials in which the sample is remembered, and *q* represents the probability that the yes alternative will be chosen by default in the absence of a memory trace.

trace of the sample stimulus is present, in which case the other choice alternative is selected. On sample trials, the strength of the memory trace fades as the retention interval increases (such that the default response strategy is overridden less often). When the memory trace fades completely, the default response strategy will always be implemented such that the pigeon will reliably choose the incorrect (i.e., no-sample) choice alternative. On no-sample trials, by contrast, no memory trace is created, so the same default strategy of primarily choosing the no-sample alternative will be implemented regardless of the size of the retention interval.

The default-response account can be presented in a formal way to reveal more clearly the predictions it makes about the way pigeons should behave on the presence-versus-absence discrimination procedure. Here, a two-state model is considered (memory trace vs. no memory trace) because it is an instantiation of the current thinking about performance on this procedure (Colwill, 1984; Wilson & Boakes, 1985). Figure 1 illustrates the events that govern performance on sample and no-sample trials according to the discrete-state model. On a sample trial, there is some probability, p, that the pigeon will remember that a sample was presented and correctly report "yes" (a *hit* in the parlance of signal detection theory). The other possibility on a sample trial, which occurs with probability $1 - p$, is that the pigeon will not remember that the sample was presented. Under these conditions, the default response strategy is implemented. That is, in the absence of a memory trace, there is some probability, q, that the pigeon will respond "yes" by default, again resulting in a hit. Alternatively, with probability $1 - q$, the pigeon will incorrectly report "no" by default, resulting in a *miss*. The same analysis can be applied to no-sample trials. If no sample was presented, then no memory trace exists, and the default response strategy will be implemented every time. Thus, the pigeon will incorrectly respond "yes" with probability q (a response known as a *false alarm*). There is also a $1 - q$ probability that the bird will correctly report "no," resulting in a *correct rejection*. The probability q is the same for the subset of sample trials involving a forgotten memory trace and for all no-sample trials because the discrete-state model assumes that the pigeon will behave one way in the presence of a memory trace and a different way in the absence of a memory trace.

The discrete-state model outlined in Figure 1 can be used to derive specific predictions about how pigeons should behave depending on the way in which reinforcement is arranged on sample and no-sample trials. According to this model, the pigeon is in one of two states when confronted with the choice stimuli. In one state, a memory trace of the sample stimulus is present, and choice performance should be governed by the relative probabilities of reinforcement for choosing "yes" and "no" in that state in the past (cf. Wixted, 1989). Typically, these probabilities would be 1.0 and 0, respectively, so the pigeon should invariably choose the "yes" key. In the other state, there is no memory trace (either because the sample was forgotten or because no sample was presented), and choice performance should be governed by the relative probability of reinforcement for choosing "yes" and "no" under these conditions. Because most of the no-memory-trace trials will be no-sample trials (with reinforcement arranged for choosing "no"), the probability of reinforcement for choosing "no" will exceed that for choosing "yes." The exact values depend on how often a memory trace is present on sample trials (a point we shall return to later).

How should a pigeon behave in the no-memory-trace state assuming that the probability of reinforcement for choosing "no" (p_n) exceeds the probability of reinforcement for choosing "yes" (p_y)? That depends on how the reinforcers are arranged. To see why this might be true, it is instructive to compare no-sample trials to a discrete-trials concurrent choice procedure. Topographically, they are identical in that, in both cases, two stimuli appear simultaneously on the side keys on each trial (without being preceded by a sample), and a single response to either stimulus terminates the trial. Behavior on this task is controlled by the reinforcement probabilities associated with the two keys. Typically, pigeons are more likely to choose the stimulus associated with the richer schedule of reinforcement. However, the way reinforcers are arranged on this procedure determines the degree of preference for the richer alternative. In a discrete-trials procedure involving probabilistic reinforcement, the probability of a reinforcer being presented for pecking a key remains constant throughout the session, so the optimal strategy is to prefer the key associated with the higher probability of reinforcement exclusively. By contrast, when reinforcers are delivered according to variable-interval (VI) schedules, the longer a pigeon perseveres on one key, the greater the probability that a reinforcer will be delivered for pecking the other key. Under these conditions, nonexclusive preference is optimal.

Bailey and Mazur (1990) used a discrete-trials procedure with reinforcers arranged probabilistically to determine the rate of acquisition of preference for one key over the other. Originally the keys had equal probabilities of reinforcement, and the pigeons divided their responses roughly equally between them. As the probabilities of reinforcement associated with the two keys were made asymmetrical, the pigeons showed near-exclusive preference for the key with the greater payoff after several hundred trials, with the rate of approach to exclusive preference being determined by the degree of asymmetry. Herrnstein and Loveland (1975) also found that once steady-state behavior was reached, most pigeons showed near-exclusive preference for the alternative with the higher probability of reinforcement when reinforcers were arranged according to variable-ratio schedules of reinforcement. Thus, when reinforcement is arranged probabilistically, pigeons maximize reinforcement by always selecting the alternative with the highest momentary probability of reinforcement (Shimp, 1966).

Alternatively, Nevin (1969) found that when reinforcers were delivered according to concurrent VI schedules in the discrete-trials procedure, the relative response rate generally matched the relative reinforcer rate. One key delivered reinforcers on a VI 1-min schedule, and the other key delivered reinforcers on a VI 3-min schedule. The pigeons responded on the key associated with the richer schedule of reinforcement approximately 75% of the time and on the other key approximately 25% of the time. Herrnstein (1961) also found with the same procedure that pigeons did not develop exclusive preference for the richer alternative when reinforcers were delivered according to VI schedules. This research demonstrates that when a discrete-trials choice procedure is used, pigeons will behave differently depending on how reinforcer delivery is arranged.

Are no-sample trials functionally equivalent to a discrete-trials concurrent choice procedure? To the extent that the choice phase of a DMTS trial is similar to a discrete-trials choice procedure, one might expect the answer to be yes. Note that the discrete-state model assumes that no-sample trials (or more precisely, no-memory-trace trials) are not only topographically identical to the discrete-trials choice procedure but are also functionally equivalent. That is, pigeons are assumed to respond on no-sample trials as if the sample trials did not exist. If so, then performance on no-sample trials should be near 100% correct when reinforcers are arranged probabilistically because in a discrete-trials procedure pigeons show near-exclusive preference for the stimulus associated with the higher probability of reinforcement.

The experiment reported below was designed to test the idea that no-sample trials are functionally equivalent to a discrete-trials concurrent choice procedure (an assumption inherent in the discrete-state model). During the first phase of the experiment, a delayed presence-versus-absence discrimination procedure was used, and all correct responses were reinforced. The second phase involved a discrete-trials concurrent choice procedure with reinforcement probabilities calculated to match those obtained on no-sample trials in the first phase (according to the discrete-state model). If no-sample trials and discrete trials are functionally as well as topographically identical, performance on these trials should be the same in both conditions when the reinforcement schedule parameters are kept constant between the conditions.

METHOD

Subjects

Eight White Carneau and King pigeons with extensive experience on the DMTS task were maintained at approximately 80% of their free-feeding weights. The birds were weighed before each experimental session and fed appropriate amounts of Purina® pigeon chow after the session. Water and grit were available in the home cages.

Apparatus

The three experimental chambers were 35 cm long, 32 cm wide, and 34 cm high. The chambers were constructed of Plexiglas except for one wall that was metal. Three Plexiglas response windows, each 6.5 cm high and 4.4 cm wide, were mounted in the metallic wall of the chamber 20 cm above the chamber floor. A VGA color monitor, which displayed the visual stimuli, was directly visible through the Plexiglas response keys. The distance from the response keys to the monitor surface was approximately 5 cm. The sample stimulus consisted of a 5-cm blue square. One choice stimulus consisted of two vertically stacked 2.5-cm red squares, and the other choice stimulus consisted of a 5-cm green circle. All of these stimuli were presented on a 6-cm white square background. Pecks were recorded via a microswitch located at the base of each response window. A pellet tray located below the center window and 4 cm above the chamber floor collected food (45-mg pellets) dispensed by a Gerbrands pellet dispenser. The chamber was not illuminated during the experimental session, and extraneous noise was masked by an exhaust fan. The chamber and the VGA monitor were enclosed in a sound-attenuating chamber. The experiment was controlled by an IBM®-compatible computer that also recorded the data.

Procedure

All of the pigeons had extensive experience on the two-sample DMTS task. In the sample/no-sample procedure used in this experiment, the probability of reinforcement for a correct response was 1.0, and the retention intervals were slowly incremented until the experimental parameters were reached. Sample trials commenced with a blue stimulus appearing in the center window. The first response emitted after 5 s terminated the stimulus and initiated the retention interval. Once the retention interval timed out, the red and green choice stimuli appeared in the side windows. For 4 of the birds, the correct choice following the blue sample was red, and for the other 4 the correct choice was green. The position of the correct choice varied pseudorandomly, with the constraint that the correct choice could not appear on the same side more than three times in a row. A correct response produced two food pellets with a probability of 1.0 for all correct responses in the baseline condition.

No-sample trials were the same as sample trials except the blue sample stimulus was not presented. Instead, a fixed-time (FT) 5-s schedule was in place at the end of the intertrial interval (ITI). When 5 s had elapsed, the retention interval was initiated. Note that no exteroceptive event signaled the end of the ITI or the beginning of the retention interval. Once the retention interval ended, the choice stimuli appeared in the side windows. For the 4 pigeons for which red was the correct choice on sample trials, green was the correct choice on no-sample trials. For the other 4 pigeons, green was the correct choice on the sample trials and red was the correct choice on the no-sample trials. A correct response was reinforced with two food pellets. An incorrect response terminated the trial. The next trial began after a 15-s ITI.

There were 100 trials per session; 50 sample trials and 50 no-sample trials. Of the 50 sample trials, about one third had a retention interval of 1 s, one third had a retention interval of 4 s, and one third had a retention interval of 20 s. No-sample trials were also divided into these same three sets of retention intervals as evenly as possible. Hence, within one session there were six types of trials (two trial types by three retention intervals). The trials were presented in pseudorandom order, with the constraint that no more than eight of one type could occur in a row. Each condition lasted at least 20 sessions and continued until the subjects' behavior stabilized, approximately 30 to 35 sessions. The stability criteria required that the slope of the line fitted to the overall proportion correct for the last five sessions could not be significantly different from zero and the asymptotic standard error associated with the slope estimate could not be greater than 0.01.

After the pigeons' behavior reached stability on the presence-versus-absence discrimination task, Phase 2 was implemented. In this phase, all trials were no-sample trials. On every trial the choice stimuli appeared on the side keys. Identical to the no-sample trials in the baseline condition, an FT 5-s schedule was in effect before the retention interval, which was either 1 s, 4 s, or 20 s. Half of the pigeons received reinforcers delivered probabilistically, and the other half of the pigeons received reinforcers delivered on mimicked VI schedules. In the probabilistic condition, probability of reinforcement for each alternative on a given trial was fixed. In the mimicked VI condition, the situation was the same except that once a reinforcer was set up on one choice alternative, it remained available until that alternative was selected (without affecting the scheduled consequences for the other alternative). This insured that the momentary probability of reinforcement would increase with the passage of time since an alternative was last chosen. An incorrect response terminated the trial. The next trial began after a 15-s ITI.

The purpose of Phase 2 was to arrange reinforcement probabilities in a discrete-trials procedure that presumably prevailed on no-memory-trace trials in Phase 1. The obtained reinforcement ratio on no-memory-trace trials in the first phase was calculated using the discrete-state model (shown in Figure 1), in the following way. The obtained false alarm rate (i.e., the probability of an incorrect "yes" response on no-sample trials) was used as the value for q, and then p was calculated using the obtained hit rate:

$$p(\text{hit}) = p + (1 - p)q. \quad (1)$$

Once p was calculated, the scheduled reinforcement probability for "yes" responses on trials theoretically not involving a memory trace (rft_y) was given by

$$\text{rft}_y = [(1 - p)N_s]/[(1 - p)N_s + N_n]. \quad (2)$$

(The reinforcement probability for "no" responses under these conditions is simply $1 - \text{rft}_y$.) In Equation 2, N_s is the number of sample trials, and N_n is the number of no-sample trials. The numerator represents the number of trials that involve a forgotten memory trace (which occurs with probability $1 - p$). Note that on all of these trials, a reinforcer was arranged for choosing the "yes" key. The denominator represents all no-memory-trace trials (the forgotten sample trials plus the no-sample trials). Thus, rft_y represents the probability of reinforcement for choosing the "yes" key in the absence of a memory trace. Because in our experiment $N_s = N_n$, Equation 2 reduces to

$$\text{rft}_y = (1 - p)/[(1 - p) + 1]. \quad (3)$$

For each bird, this equation was used to compute the scheduled Phase 2 reinforcement probabilities for what was the sample ("yes") alternative in Phase 1. The corresponding reinforcement probabilities for what was the no-sample ("no") alternative in Phase 1 were set to $1 - \text{rft}_y$.

RESULTS

For each pigeon, the data were averaged over the last five sessions of each phase. Figure 2 shows the proportion correct for sample and no-sample trials as a function of retention interval for each pigeon as well as the group data. All of the pigeons exhibited the same pattern of behavior: Performance on no-sample trials was constant across retention intervals, and performance on sample trials decreased as a function of retention interval. Performance on sample trials at the 20-s retention interval averaged 30% correct, which is well below chance performance. This result is consistent with the discrete-state model outlined in Figure 1.

Table 1 presents the hit and false alarm

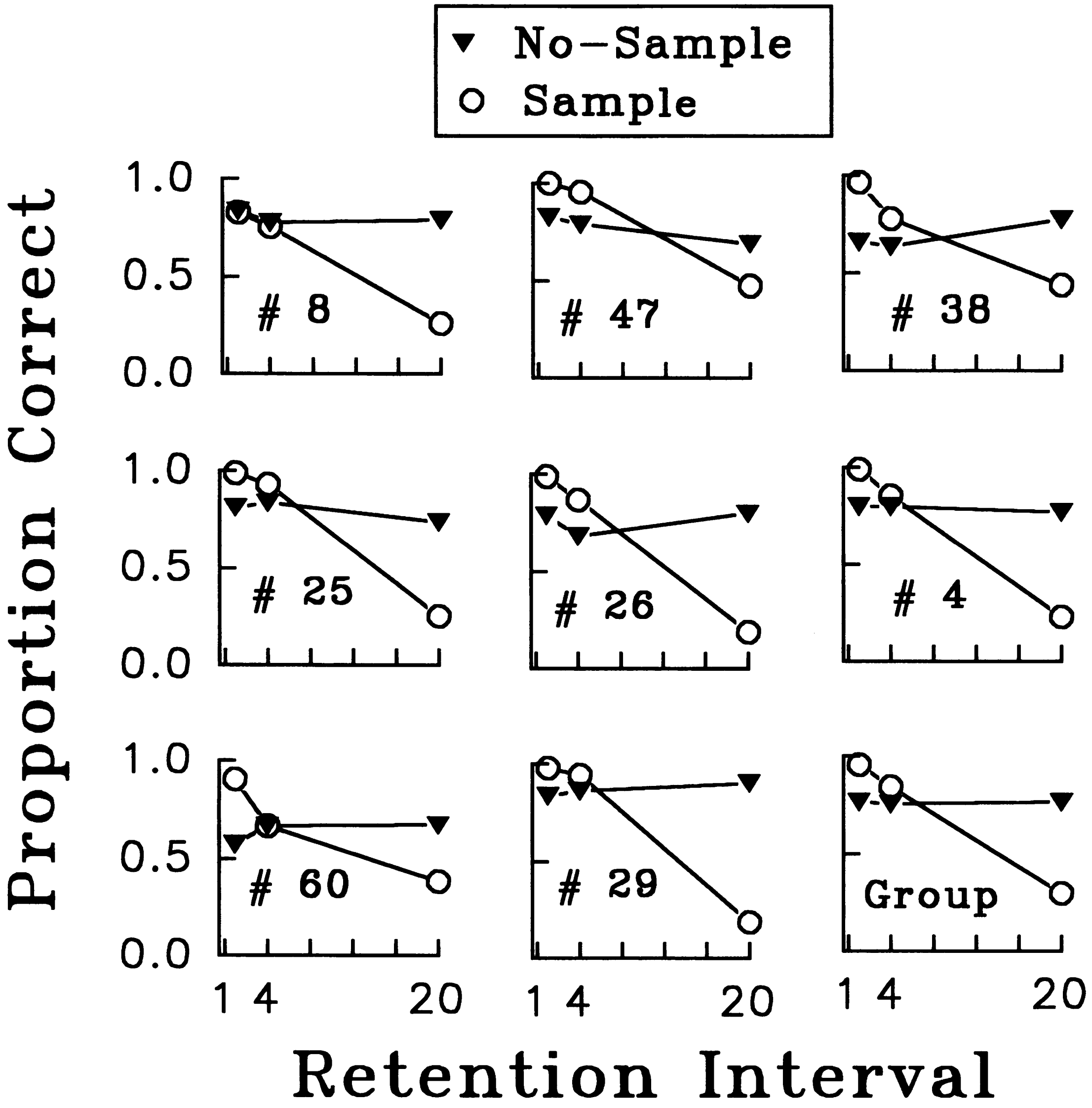

Fig. 2. The proportion of correct responses on sample and no-sample trials as a function of retention interval. These data are from individual pigeons in Phase 1 as well as the group average.

rates (averaged across retention interval) for each pigeon in Phase 1, the calculated values of p based on Equation 1, and the scheduled reinforcement contingencies that were in effect during Phase 2 on what were the sample and no-sample alternatives in Phase 1 (based on Equation 3). These reinforcement contingencies theoretically match those that were in effect on no-sample trials during Phase 1.

The average results from Phase 2 are displayed in Figure 3, which shows the choice proportion for the stimulus associated with the richer schedule of reinforcement. For comparison purposes, the proportion of correct choices on no-sample trials from Phase 1 are also shown. The bars on the left side of the graph are results from the matching condition in which reinforcers were delivered according to time-based schedules. Preference for the richer alternative was greater than .5 but was less than in Phase 1. The bars on the right side of the graph are from the pigeons

Table 1

Subjects' hit and false alarm (FA) rates during Phase 1, theoretical probabilities of an intact memory trace on sample trials (*p*), and scheduled Phase 2 reinforcement probabilities on what were sample and no-sample choice alternatives in Phase 1.

	Phase 1			Phase 2	
Subject	Hit rate	FA rate	*p*	Sample	No-sample
29	.72	.13	.68	.24	.76
38	.73	.31	.61	.28	.72
47	.82	.22	.77	.19	.81
8	.68	.14	.63	.27	.73
25	.75	.23	.67	.24	.76
26	.69	.24	.59	.29	.71
60	.66	.36	.47	.35	.65
4	.70	.21	.62	.28	.72

in the other condition in which reinforcers were arranged probabilistically. Three of these 4 subjects showed near-exclusive preference for the richer alternative. Subject 60 developed an extreme left side bias that drove preference down to 50%, because the correct stimulus appeared on the left side 50% of the time. Subject 60 emitted more than 75% of all responses on the left key.

DISCUSSION

This experiment was designed to test the simplest default response model of performance on a delayed presence-versus-absence discrimination procedure. The model in question holds that no-sample trials are functionally equivalent to a discrete-trials concurrent choice procedure because, in both cases, choice stimuli are presented without being preceded by a sample. If this idea is correct, then choice performance on the two procedures should be affected in the same way when asymmetrical reinforcement probabilities are arranged. More specifically, if reinforcers are arranged probabilistically, then exclusive preference for the richer alternative should be observed. Our findings did not support this idea. In Phase 1, performance on no-sample trials was not exclusive, even though, in the absence of a memory trace, the no-sample choice alternative was theoretically associated with a much higher probability of reinforcement than the sample choice alternative. In Phase 2, when sample trials were eliminated (thereby transforming the task into a discrete-trials concurrent choice procedure), performance approached exclusive preference for the richer alternative for 3 of the 4 birds tested. Why did the presence of sample trials in Phase 1 inhibit the development of exclusive preference on the no-sample trials? Signal detection theory offers one possible explanation.

Signal Detection Theory

Previously, the absence of a decline in performance as a function of retention interval has been explained on the basis of a default response strategy. An alternative hypothesis, suggested by Wixted (1993), is based on signal detection theory. This theory, unlike the discrete-state model, assumes that the same, imperfect, decision strategy is involved in both sample and no-sample trials. Figure 4 illustrates signal detection theory. The analysis assumes that choice responding is governed by the strength of evidence that a sample was presented on a given trial. On both sample and no-sample trials, strength of evidence is assumed to vary from trial to trial according to identically shaped Gaussian distributions. The average strength of evidence on sample trials is generally higher than that on no-sample trials because of the delayed effect of the sample stimulus. However, even on no-sample trials, some evidence for the presence of a sample is assumed to exist, perhaps due to the cumulative effect of many previously presented samples (cf. Wright, Urcuioli, & Sands, 1986).

Because strength of evidence is a continuous dimension, and because the signal and noise distributions partially overlap, no errorless decision strategy exists. Signal detection theory assumes that, to solve the task, the subject has a criterion value above which the "yes" alternative is selected and below which the "no" alternative is selected. The decision criterion is placed to maximize the number of reinforcers obtained over the session and can be theoretically manipulated by varying the relative payoff for correct "yes" and "no" responses. For example, if correct "yes" and "no" responses yield reinforcers with probabilities of 1.0 and .20, respectively, the decision criterion would be placed relatively far to the left so as not to miss the many reinforcers arranged for correct "yes" responses (Wixted, 1993).

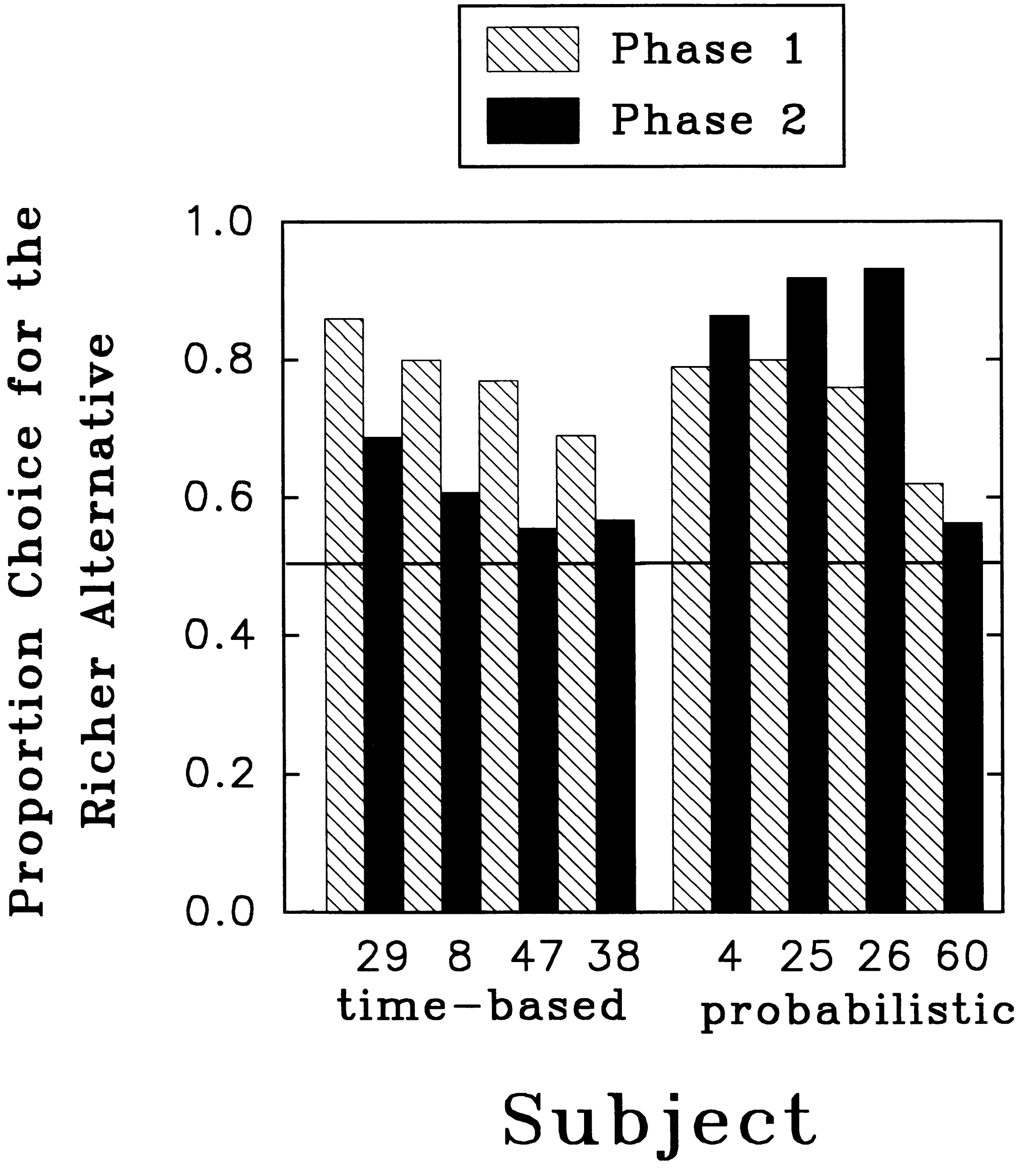

Fig. 3. Proportion choice for the richer alternative during Phase 1 on no-sample trials (hatched bars) and Phase 2 on all trials (solid bars) for all pigeons.

How does this model account for the pattern of results shown in Figure 2? With regard to the flat retention function in no-sample trials, the important point is that the position of the noise distribution is not determined by factors that occur on a given trial. For that reason, the distribution remains fixed as the retention interval on a particular trial increases. The decision criterion is also fixed because, as discussed above, its placement is determined by experience aggregated over many trials. Thus, on no-sample trials, the

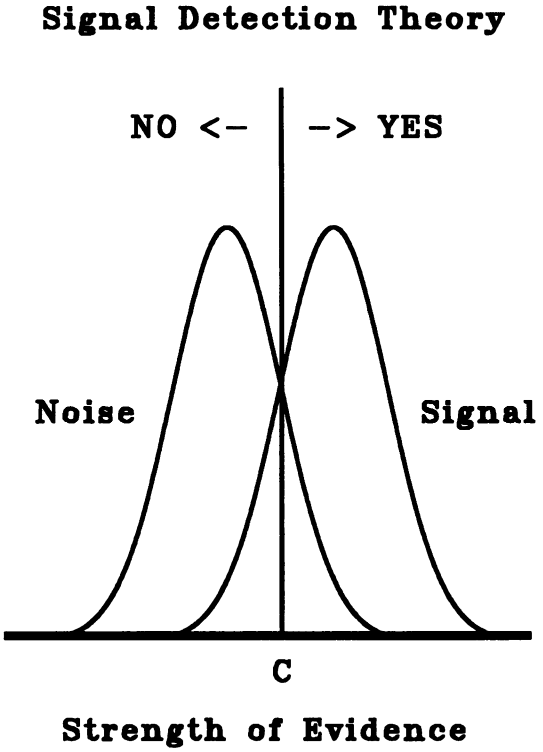

Fig. 4. Hypothetical signal and noise distributions from signal detection theory corresponding to sample and no-sample trials, respectively. The decision criterion is represented by C.

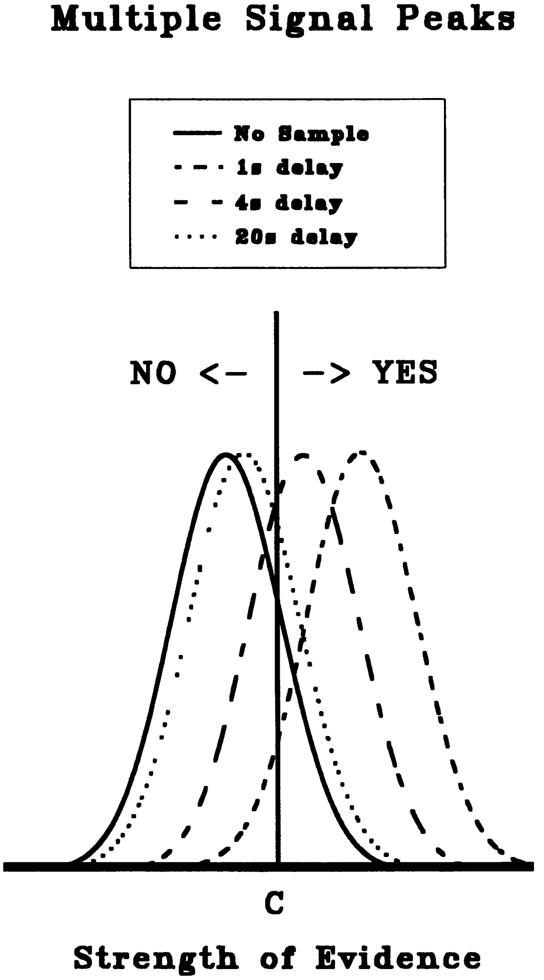

Fig. 5. Hypothetical multiple signal and noise distributions from signal detection theory corresponding to varying retention intervals using sample and no-sample trials, respectively. The decision criterion is represented by C.

area to the left of the criterion (which corresponds to the proportion of trials on which the subject correctly chooses the "no" key) remains constant across variations in the size of the retention interval.

The signal distribution, on the other hand, does not remain fixed as a function of retention interval, because the delayed effect of the sample presumably weakens as a function of time since the sample was presented. Figure 5 illustrates a signal detection model with three signal peaks corresponding to three different retention intervals. When the retention interval is short, the mean of the signal distribution greatly exceeds the mean of the noise distribution. Under these conditions, the signal is easily distinguished from noise and accuracy should be (and is) high on both kinds of trial. As the retention interval increases, the signal distribution moves toward (and increasingly overlaps) the noise distribution. Note that when the signal distribution overlaps the noise distribution completely, the proportion of hits and correct rejections must sum to one. Thus, if no-sample performance is greater than 50% correct at a long retention interval (which it usually is), sample performance under these conditions must be correspondingly less than 50% correct. In the present experiment, accuracy on no-sample trials was approximately 80% correct at all retention intervals (Figure 2). According to a signal detection analysis, this means that the criterion was placed so that 80% of the noise distribution was to the left of it and 20% was to the right of it. If the signal is indistinguishable from noise (e.g., at a 20-s retention interval), then only 20% of the signal distribution would lie to the right of the decision criterion. Thus, on only 20% of those trials would the pigeon correctly choose "yes." This corresponds to the pattern of data shown in Figure 2.

The discrete-state model has no provision to explain why performance on no-sample trials changes when the other half of the trials in the session shift from sample trials to no-sample trials (although the theory could be modified to correct that problem). Signal detection theory, though, provides a natural account of these results. What prevents the occurrence of exclusive preference on no-sample trials, according to this account, is the effect of sample trials on the placement of the decision criterion. If the decision criterion were adjusted to pick up all reinforcers arranged on no-sample trials (by moving it far to the right in Figure 5), the cost would be to lose reinforcers arranged on sample trials. This opposing force prevents the appearance of exclusive preference on no-sample trials. When the sample trials are removed (as in Phase 2 of the present experiment), this opposing force is removed as well, thereby resulting in near-exclusive preference for those pigeons who continued to receive reinforcers arranged probabilistically.

Analyzing Asymmetrical Forgetting Functions

The forgetting functions shown in Figure 2 are notable because performance on one kind of trial remained constant and well above 50% correct while performance on the other decreased rapidly to well below 50% correct. Precisely this same pattern has been observed in a variety of other situations that, procedurally at least, do not require a presence-versus-absence discrimination. One well-known example is memory for event duration in pigeons. In a typical experiment of this kind, a sample stimulus is presented for either 2 or 8 s and is later followed by a choice between red and green. A response to red is reinforced following the short sample, and a response to green is reinforced following the long sample. The usual finding observed with this procedure is that performance following the long sample decreases rapidly to below-chance levels as the retention interval increases, and performance following the short sample remains accurate (and often remains unchanged) regardless of the size of the retention interval (Spetch & Wilkie, 1982, 1983).

These data are worth considering here because the theoretical analyses applied to memory for event duration could be applied to the findings shown in Figure 2 as well. Two related accounts of the apparent "choose-short" effect will be considered here. One interpretation is that the remembered duration of an event shrinks with the passage of time. Thus, immediately after it is presented, a long-duration sample will be accurately represented (leading to accurate performance). After a long retention interval, however, the representation will shrink and the long-duration sample will actually be remembered as a short-duration sample (eventually leading to below-chance performance). The theoretical decrease in the representation of event duration with the passage of time is known as *subjective shortening* (Spetch & Wilkie, 1982, 1983).

Exactly the same reasoning could be used to explain the data reported here if the experiment is construed as a test of memory for event duration. That is, instead of a delayed discrimination between 2-s and 8-s samples, we arranged a delayed discrimination between 0-s and 5-s samples. As is typically found, performance following the short (0-s) sample remained constant, and performance following the long (5-s) sample dropped rapidly as the retention interval increased. The reason for this, it could be argued, is that the remembered duration of the 5-s sample decreased rapidly as a function of time.

Although such an interpretation cannot be ruled out, it seems more parsimonious to apply the presence-versus-absence signal detection analysis to both our data and to the event duration data ordinarily explained in terms of subjective shortening. According to this idea, pigeons in an event duration experiment actually respond based mainly on the presence or absence of the 8-s stimulus. Evidence that this might be true was reported by Kraemer, Mazmanian, and Roberts (1985). In that experiment, pigeons were trained to choose among three choice alternatives depending on whether the sample was 0, 2, or 8 s in duration (i.e., no sample, short, or long). As the retention interval increased following the long sample, pigeons became increasingly likely to choose the no-sample choice alternative. If the subjective shortening model were correct, pigeons should have first shown a tendency to choose the 2-s alternative incorrectly as the memorial representation decreased in duration. The authors concluded that their findings were more consistent with the idea that in a typical 2-s versus 8-s delayed discrimination, pigeons respond after a long delay as if no sample had been presented. Because no sample is more like a 2-s sample than an 8-s sample, a choose-short bias emerges.

A second theoretical analysis that is not necessarily incompatible with the subjective shortening model was proposed by Fetterman and MacEwen (1989). These authors used the behavioral detection model proposed by Davison and Tustin (1978) (and extended to the memory situation by White & McKenzie, 1982) to analyze asymmetrical forgetting functions produced by a procedure very similar to that described above. Instead of using short versus long samples, however, their procedure required either 10 or 40 responses to the sample. When the retention interval was increased, performance remained well above 50% correct following the sample associated with the smaller FR requirement yet decreased rapidly to below 50% correct following the sample associated with the larger FR requirement. They termed this result the "choose-small" effect and noted its obvious similarity to the choose-short effect discussed above.

The behavioral detection model was used to interpret the choose-small effect. This model yields two measures of performance, a discriminability measure analogous to d' of signal detection theory (log d) and a bias measure (log b):

$$\log d = 0.5 \log[(B_w B_z)/(B_x B_y)]$$

$$\log b = 0.5 \log[(B_w B_y)/(B_x B_z)]$$

where B_w and B_z represent correct responses following small- and large-ratio samples, respectively, and B_x and B_y represent incorrect responses following small- and large-ratio samples, respectively. The discriminability measure, log d, basically captures how well the animal can discriminate a small-ratio sample from a large-ratio sample after a delay. The bias measure, log b, represents the animal's bias to choose one alternative over the other (e.g., due to a color preference).

When the retention interval increased, B_w and B_x (correct and incorrect responses following the small-FR sample) remained essentially constant, whereas B_z (correct responses following the long-FR sample) decreased and B_y (incorrect responses to the short alternative following the long-FR sample) increased correspondingly. Thus, as the retention increased, log d decreased, reflecting the increasing difficulty of discriminating the small-FR sample from the large-FR sample. The measure of bias, log b, necessarily increased (because of the changes in B_z and B_y), apparently reflecting an increasingly strong bias to choose the alternative associated with the small-FR sample as the retention interval increased. A similar conclusion would be reached if the behavioral detection model were applied to the data shown in Figure 2. That is, the behavioral detection model would indicate an increasing bias to choose the no-sample alternative as the retention interval increased.

Why should bias for the small-FR alternative (or, in our case, the no-sample alternative) increase as the retention interval increases? One possible explanation is provided by the subjective shortening account. If a representation of the *number* of sample responses decreases with time since the sample was presented (which theoretically occurs for event duration as well), an increasing bias to choose the small-FR alternative would be observed. On the other hand, it may be simpler to assume that bias did not actually change as the retention interval increased, and that the small-FR samples were effectively nonevents. Indeed, Fetterman and MacEwen (1989) performed an additional manipulation that lends support to this idea. Specifically, they inserted occasional probe trials in which no sample was presented at all. On these trials, the pigeons reliably chose the comparison associated with the smaller FR requirement. This result is consistent with the idea that the pigeons were, to an extent, treating the small-FR sample like a nonevent. If so, then the signal detection model shown in Figure 5, which assumes a fixed decision criterion (and, therefore, no change in bias), could accommodate these results.

Conclusion

The data reported in Figure 2 are most readily explained by the signal detection analysis illustrated in Figures 4 and 5. The overall pattern of data are not consistent with the simplest default response model of performance. The signal detection analysis also appears to provide an account of performance on other tasks that reliably yield data very similar to our results. In particular, the choose-short effect and the choose-small effect might be explained by assuming that pigeons display a presence-versus-absence discriminative strategy even though that is not the strategy the experiment was designed to induce[1] (cf. Kraemer et al., 1985). Indeed, whenever qualitatively different sample stimuli yield asymmetrical forgetting functions, the possibility that the animal is responding on the basis of the presence or absence of the more salient sample should be considered.

REFERENCES

Bailey, J. T., & Mazur, J. E. (1990). Choice behavior in transition: Development of preference for the higher probability of reinforcement. *Journal of the Experimental Analysis of Behavior, 53,* 409–422.

Colwill, R. M. (1984). Disruption of short-term memory for reinforcement by ambient illumination. *Quarterly Journal of Experimental Psychology, 36B,* 235–258.

Davison, M. C., & Tustin, R. D. (1978). The relation between the generalized matching law and signal-detection theory. *Journal of the Experimental Analysis of Behavior, 29,* 331–336.

Fetterman, J. G., & MacEwen, D. (1989). Short-term memory for responses: The choose-small effect. *Journal of the Experimental Analysis of Behavior, 52,* 311–324.

Grant, D. S. (1991). Symmetrical and asymmetrical coding of food and no-food samples in delayed matching in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 17,* 186–193.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4,* 267–272.

Herrnstein, R. J., & Loveland, D. H. (1975). Maximizing and matching on concurrent ratio schedules. *Journal of the Experimental Analysis of Behavior, 24,* 107–116.

Kraemer, P. J., Mazmanian, D. S., & Roberts, W. A. (1985). The choose-short effect in pigeon memory for stimulus duration: Subjective shortening versus coding models. *Animal Learning & Behavior, 13,* 349–354.

Nevin, J. A. (1969). Interval reinforcement of choice behavior in discrete trials. *Journal of the Experimental Analysis of Behavior, 12,* 875–885.

Sherburne, L. M., & Zentall, T. R. (1993). Asymmetrical coding of food and no-food events by pigeons: Sample pecking versus food as the basis of the sample code. *Learning and Motivation, 24,* 141–155.

Shimp, C. P. (1966). Probabilistically reinforced choice behavior in pigeons. *Journal of the Experimental Analysis of Behavior, 9,* 443–455.

Spetch, M. L., & Wilkie, D. M. (1982). A systematic bias in pigeons memory for food and light duration. *Behavior Analysis Letters, 2,* 267–274.

Spetch, M. L., & Wilkie, D. M. (1983). Subjective shortening: A model of pigeons memory for event duration. *Journal of Experimental Psychology: Animal Behavior Processes, 9,* 14–30.

White, K. G., & McKenzie, J. (1982). Delayed stimulus control: Recall for single and relational stimuli. *Journal of the Experimental Analysis of Behavior, 38,* 305–312.

Wilson, B., & Boakes, R. A. (1985). A comparison of the short-term memory performance of pigeons and jackdaws. *Animal Learning & Behavior, 13,* 285–290.

Wixted, J. T. (1989). Nonhuman short-term memory: A quantitative reanalysis of selected findings. *Journal of the Experimental Analysis of Behavior, 52,* 409–426.

Wixted, J. T. (1993). A signal detection analysis of memory for nonoccurrence in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 19,* 400–411.

Wright, A. A., Urcuioli, P., & Sands, S. F. (1986). Proactive interference in animal memory. In D. F. Kendrick, M. E. Rilling, & M. R. Denny (Eds.), *Theories of animal memory* (pp. 101–125). Hillsdale, NJ: Erlbaum.

Received November 28, 1994
Final acceptance June 12, 1995

---

[1] Thomas R. Zentall presented this idea at the 1994 Winter Conference on Animal Learning.