

PIGEONS' DELAYED MATCHING TO SAMPLE ERRORS ARE NOT ALWAYS DUE TO FORGETTING

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ABSTRACT

A common assumption is that errors in choosing the stimulus that matches a sample that is no longer present are due to forgetting of the sample. However, when feedback for choosing the correct or incorrect stimulus (food or no food, respectively) required additional keypecks, pigeons pecked more slowly after incorrect choices in apparent anticipation of nonreward, indicating that they had not forgotten the sample despite their choice error. Consequently, delayed matching errors are not an uncontaminated index of forgetting.

Key words: delayed matching to sample; latency; choice errors; forgetting.

Memory processes play an important role in many contemporary accounts of learning in animals (see recent volumes by Honig and James, 1971; Hulse, Fowler and Honig, 1978; Medin, Roberts and Davis, 1976; Spear, 1978). One variety of memory has been postulated to have the functional properties of a temporary calculator-like storage register. Such 'working memory' (Honig, 1978; Olton, 1978) frequently is studied with paradigms such as delayed matching to sample (DMTS). On a DMTS trial a briefly presented sample stimulus such as a patch of red or green light is followed after a brief delay by two comparison stimuli, one of which matches the sample. Subjects are permitted one response per trial: a response to the matching but not the nonmatching comparison is rewarded.

A key assumption made by those using the DMTS procedure to study working memory is that errors in choosing the matching comparison reflect forgetting of the sample. We tested this assumption using a variant of the DMTS procedure.

METHOD

Subjects

Four experimentally-naive King pigeons were maintained at approximately 85 percent of their free-feeding weight.

Apparatus

The birds were tested in conventional ventilated operant conditioning chambers equipped with a food hopper and a horizontal array of three pecking keys, each backed with a stimulus projector capable of projecting various colored light onto the key. A NOVA 3/12 computer (Data General Corporation) was programmed to control experimental events and record the subjects' behavior.

Procedure

The birds were trained to eat mixed grain from the food hopper when it was raised and illuminated and then to peck response keys illuminated with red or green light for 5-sec access to grain. Next, they were trained to match to sample. Illumination of the center key with a sample (red on half of the trials; green on the other half) signalled the start of the trial. A single peck to this key was followed by illumination of the two side keys with red and green comparison stimuli (positions counterbalanced over trials). A peck to the comparison that matched the sample (a correct choice) produced grain, followed by the 15-sec intertrial interval; a peck to the nonmatching comparison (an error) produced only a 20-sec intertrial interval.

After matching-to-sample training had produced a high level of correct responding, the birds received training on a modified DMTS task (Wilkie and Spetch, 1978). As before, trials were separated by a 15-sec intertrial interval and began with the illumination of the center key with red or green. The eighth peck to this key terminated this sample and initiated a delay of either 0.25 sec (Bird 3), 0.75 (Bird 1), 1 (Bird 4), or 2 sec (Bird 2), which was followed by illumination of the side keys with red and green. (Delay values were chosen during preliminary sessions such that errors occurred fairly often.) The first peck to either of the side keys caused the other side key to be turned off. Although this first peck determined the outcome of the trial, 31 additional pecks to the chosen side key were required to complete the trial. Trials ended with grain only when the first peck was to the matching comparison.

Sessions were conducted daily and consisted of as many trials as the subjects could complete within a 45-min period, to a maximum of 40. On each trial latency to choose either of the comparisons (time measured in centiseconds from onset of comparisons to first peck), completion time (time measured in centiseconds from first peck to the last required peck), and whether the choice was correct or incorrect were recorded on disk for subsequent analysis using the Michigan Interactive Data Analysis System (Statistical Research Laboratory Staff, University of Michigan, 1976).

Subjects were exposed to these procedures for a minimum of 60 sessions, at which time performance appeared stable to visual inspection. Data from the last 20 sessions (825, 693, 813 and 694 trials for Birds 1, 2, 3 and 4, respectively) were chosen for detailed analysis.

RESULTS

Basic findings

Figure 1 shows percentage of trials birds correctly chose matching comparisons. Data are shown in four blocks of trials; each block comprised an equal number of trials, except for the final block in which the few residual trials were included. Average percent correct over the four blocks for Birds 1 to 4, respectively, was 60.3, 55.3, 77.8 and 79.5.

Figure 2 shows in four blocks of trials completion times after correct and incorrect first-peck choices. Each bird took more time to complete the required 31 pecks after making an error on the first peck than after correctly choosing the matching comparison on the first peck. Average completion times over the four blocks for Birds 1 to 4, respectively, after a correct choice were 6.95, 9.33, 10.88 and 12.13 sec. The corresponding times after errors were 51.8, 10.13, 11.79 and 14.33 sec.

Interpretations

Three interpretations of the fact that completion time was shorter after correct choices than after incorrect choices seem possible.

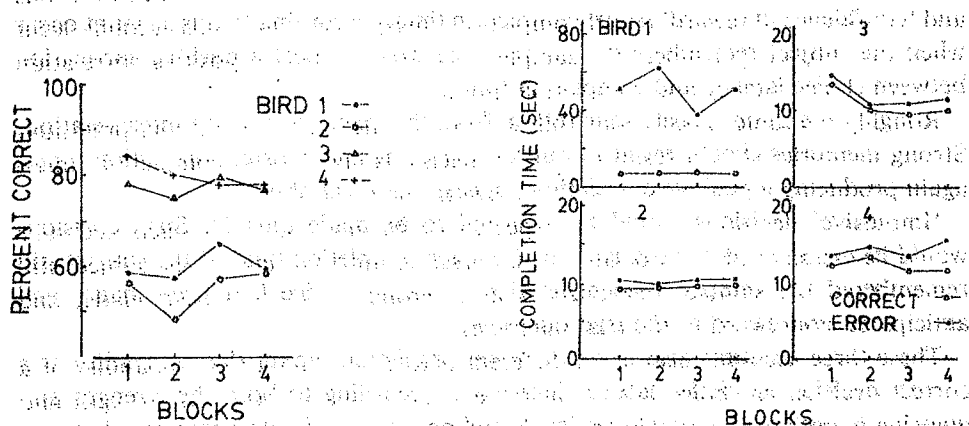


Figure 1. Percentage of trials birds chose correct (matching) comparison over four blocks of trials.

Figure 2. Average time (in seconds) to complete the 31 pecks required after initial choice of matching (correct) or nonmatching (incorrect) comparison over four blocks of trials.

(1) The pigeons could have made 'impulsive' choices on certain trials and then, in anticipation of nonreward on trials on which the wrong comparison was impulsively chosen, took longer to complete the trial. The key idea in this interpretation is that errors may arise in the absence of forgetting about the sample.

(2) The second interpretation is based on the assumption that the 'strength' of memory for a sample weakens over time and that the rate of this decay is variable. If it is assumed that greater memory strength results in both more accurate and more rapid responding, then correct choices should be correlated with faster completion times. Conversely, weak memory strength would be correlated with more errors and slower completion times.

(3) A third interpretation is based on the assumption that when the pigeon cannot remember the sample it 'guesses' about which stimulus had appeared as the sample. Such guesses should produce more errors and be reinforced less frequently than choices made when the sample is remembered. If the pigeon was capable of discriminating whether it remembered the sample or simply guessed, then slower completion times after errors would be expected.

It seems possible to distinguish between these three accounts of why completion times after errors are longer than completion times after correct choices by considering choice latency (i.e., time between onset of correct and incorrect comparisons and responding to either of these). First, consider the guessing interpretation. When the subject remembered the sample one would expect quicker decisions and more confidence in trial outcome than when the subject guessed. (This argument parallels one in the signal detection literature (e.g., Terman and Terman, 1973): latency to make a positive 'yes' response decreases as distance along the sensation continuum from the criterion point increases.) Because quick decisions and 'confidence in reward' (short completion times) according to this account occur when the subject remembers the sample, one would expect a positive correlation between choice latency and completion times.

Roughly the same expectations follow from the memory strength interpretation. Strong memories should result in quicker decisions and shorter completion times, again producing a positive correlation between these variables.

'Impulsive' decisions would be expected to be made quickly. Such decisions would be expected to be associated with longer completion times if the subject still remembered the sample, recognized that a wrong choice had been made, and anticipated nonreward as the trial outcome.

These three accounts also make different predictions about the probability of a correct decision as choice latency increases. According to both the strength and guessing hypotheses, longer latencies should be associated with progressively lower levels of correct choice. According to the impulsive hypothesis on the other hand, short latency choices should be associated with a lower level of accuracy than at least some longer latency choices, at least up to a point (very long latencies would be expected to result in forgetting, hence lower levels of accuracy).

According to the guessing and strength hypotheses, birds with the shortest choice latencies should be correct more often than birds with longer choice latencies. The impulsive hypothesis predicts the opposite.

Additional analyses of the data

The correlations (r) between choice latency and completion time for Birds 1 to 4, respectively, were -0.2031 , 0.237 , 0.000 and 0.0959 . These data do not provide clear support for any of the hypotheses. Only two of the four correlations were positive as predicted by the strength and guessing hypotheses; only one was negative as predicted by the impulsive hypothesis.

Figure 3 shows completion time after correct and incorrect decisions as a function of 'short', 'medium' and 'long' latencies to choose a comparison. Latencies are shown in cumulative proportion format. To facilitate graphic presentation the shortest one percent and longest one percent of latencies were excluded from the analysis. The shortest 29 percent of all latencies for a subject were defined as 'short' and the longest 29 percent as 'long'; 'medium' latencies were all those intermediate between the two former sets. Percent correct choices as a function of these three latency classes are also shown.

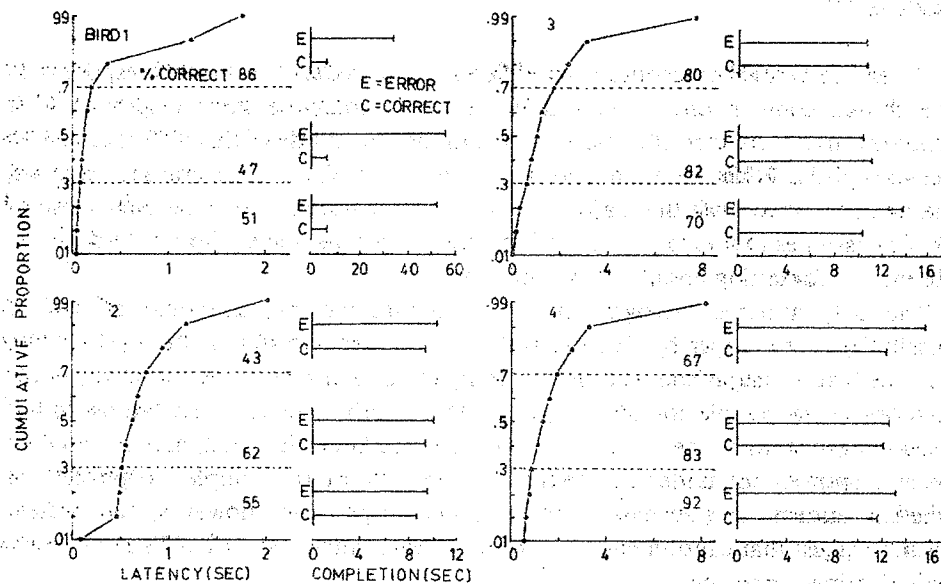


Figure 3. Latencies (in seconds) to choose one of the comparisons are shown in cumulative proportion format (10 percent of latencies are less than the latency value associated with the cumulative proportion value of 0.1; 50 percent are less than the value associated with 0.5, etc.). Percentage correct choices for trials on which choice latency was 'short' (shortest 29 percent of latencies), 'long' (longest 29 percent of latencies), or 'medium' (all of the rest) are shown. Average completion times (in seconds) after correct and incorrect choices for trials of these latency groupings are also shown.

Consistent with the impulsive hypothesis, the birds with the longest choice latencies matched most accurately. Median choice latencies for Birds 1 to 4, respectively, were 0.13, 0.62, 1.02 and 1.30 sec. The corresponding overall accuracy levels were 60.3, 55.3, 77.8 and 79.5. These values correlate well ($r = 0.82$).

Three of the four birds (Bird 4 being the exception) showed the increase in percent correct choices for at least one of the longer choice latencies groupings as predicted by the impulsive hypothesis and contrary to both the strength and guessing hypotheses. Bird 1 was correct 86 percent of the time on long latency choices as compared to 51 percent correct on short latency choices. Bird 2 was correct 62 percent of the time on medium latency choices as compared to 55 percent correct on short latency choices. Bird 3 was correct on at least 80 percent of longer latency choices as compared to 70 percent correct on short latency choices. Bird 4, on the other hand, showed a progressive decline in correct choices as choice latency increased.

Also consistent with the impulsive hypothesis, all birds had longer completion times after incorrect than after correct choices for quick (short) decisions. Three birds (Bird 3 being the exception) took longer to complete the trial after errors, regardless of choice latency.

DISCUSSION

When the DMTS procedure is modified so as to require additional responses to the chosen comparison, pigeons take longer to complete these responses after incorrect than after correct choices, although the magnitude of this difference varies between birds. While such a difference could be explained by several mechanisms, the one consistent with the majority of the present results (and especially those of Bird 1) assumes that errors on occasion arise from 'impulsive' choices made in the absence of forgetting about sample information.

The only apparent recognition in the animal memory literature of such a possibility is in a paper by Roberts and Grant (1978) who stated that pigeons may "... peck at a comparison key without comparing the information on the key to the memory of the sample stimulus" (p. 79). These authors believe that 'autoshaping' (pecks engendered by the contiguous association of keys with food) may account for these responses not under the control of memory of the sample. Regardless of whether autoshaping accounts for impulsive responding, however, the present results suggest that caution must be exercised when interpreting DMTS error scores as indicating forgetting.

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