DELAYED ALTERNATION IN THE PIGEON¹

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Pigeons were studied in a delayed-response task requiring alternation of key pecks on two response keys. Blackouts of from 1 to 10 sec intervened between successive choices on the two keys.

The following results were obtained: (1) Birds performed at well above chance accuracy on all the delays tested. Accuracy was generally lowest at 1- and 10-sec delays. (2) Overt postural orientations during the delay interval appeared to mediate accurate key-pecking behavior. (3) The shape of the delay *vs.* accuracy function was discussed in terms of the possibly confounding influences of (a) stimulus "trace" variables, and (b) aversive effects of the time outs produced by incorrect responding.

In the delayed-response task, a subject is required to select a response on the basis of some previous event which is no longer physically present. Classical experiments in this area (*e.g.*, Hunter, 1913) have typically examined such factors as the length of the delay between past event and present choice, and the details of the animal's behavior during the delay interval.

This experiment was a study of one type of delayed response in the pigeon. Birds were first trained to alternate pecks on two response keys in order to obtain reinforcement; then several different delay intervals (here, blackouts) were instituted between key pecks. Accuracy of responding in this delayed-alternation situation was examined as a function of the length of the delay interval for values up to 10 sec. Performance on this task may be compared with that on Blough's (1959) delayed-matching procedure, in which pigeons, after various delay intervals, matched a previously presented stimulus by pecking a corresponding response key.

METHOD

Subjects

The subjects were eight White Carneaux hen pigeons, 4 to 9 years old. They had already been trained to peck a key for grain reinforcement in a previous experiment (Hearst, 1961). The birds were maintained at approximately 75% of their free-feeding weights.

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Apparatus

A standard experimental box (Foringer) was used. Except during blackout periods, the box was illuminated by a 110-VAC, 6-watt shielded houselight, which was situated on the rear wall of the chamber.

Two translucent response keys were mounted on either side of the front panel of the chamber. These keys were illuminated by orange Xmas-tree lamps during experimental trials. A small light went on in the magazine opening while grain reinforcement was available. The blower in the experimental box and an external white-noise generator masked outside sounds.

A system of relays, timers, and counters automatically controlled and tabulated correct and incorrect responses, reinforcements, delay intervals, etc.

Procedure

The birds were trained in a delayed-alternation situation (left key → right key → left key → , etc.) in which an incorrect response produced a 2-sec blackout. The next opportunity to respond was therefore delayed until the blackout had terminated and another trial had begun.² Perseveration on the in-

²Prior procedures in which the *immediate* correction of an incorrect response was permitted (*i.e.*, incorrect responses did not produce blackouts) did not lead to much better than chance accuracy in all the birds, even at relatively short delay durations. On this procedure, blackouts occurred only after grain reinforcements. Only the first postblackout response on each trial was used in the calculation of response accuracy.

correct key (the last-rewarded key) continued to produce 2-sec blackouts; no reinforcement was possible until the subject switched to the other key. A correct response produced a 1-sec grain reinforcement followed by a 2-sec blackout. By consistently alternating between the two keys from trial to trial, the subjects could attain perfect accuracy. Birds were tested daily, except for weekends. Individual sessions lasted as long as it took each subject to obtain a total of 200 reinforcements.

Response accuracy was defined by a "percent correct" measure derived from the fraction: Total Correct Responses/Total Responses (Correct + Incorrect).

Within a few sessions, all birds showed some learning of the delayed-alternation task (more than 50% accuracy). After 10 to 15 daily sessions, every subject was reliably performing at better than 75% accuracy. Several additional sessions were then run during which the accuracy of most subjects rose to above 80%.

The birds were next placed on a procedure which enabled the daily testing of four different delay intervals (1, 2, 3, and 5 sec). On a given trial (*i.e.*, when the houselight was on and the key lights illuminated) a correct key-peck produced a 1-sec reward followed by one of the four possible blackout durations. An incorrect response (*i.e.*, a response on the last-rewarded key) produced only the appropriate blackout duration. Subjects were given 75 reinforcements daily at each blackout duration for a total of 300 reinforcements. The four blackout durations were programmed in blocks of 25 trials at each duration, but were otherwise scheduled in a mixed order throughout the session. For example, the bird might first receive 25 reinforcements at a 1-sec delay interval, then 25 reinforcements at a 5-sec delay, then 25 reinforcements at the 2-sec duration, etc., until three blocks of 25 reinforcements had occurred for each of the four durations.

The subjects remained on this procedure for several months, by which time their daily scores were very reliable and stable from day to day. The effects of several drugs were then tested on the delayed-alternation base line; however, the results of these tests will not be described here.

After these drug sessions, the four most reliable subjects (in terms of weight stability

and behavioral performance) were exposed to delays of 1, 3, 5, and 10 sec daily; response accuracy was determined for these four delay intervals. Otherwise, the procedure was exactly the same as when delays of 1, 2, 3, and 5 sec were tested.

RESULTS

Figure 1 shows the relationship between response accuracy and length of delay for each

Fig. 1. Response accuracy as a function of delay interval for the eight subjects tested with delays of 1, 2, 3, and 5 sec.

of the eight subjects, when the four test durations were 1, 2, 3, and 5 sec. Data points represent mean "per cent correct" values for the last 5 days on this procedure.

All birds showed a high degree of accuracy in the task, but individual functions were not all of the same form. At least half the subjects displayed greatest accuracy at the intermediate delay values (2 and 3 sec). There is little suggestion of a steadily decreasing accuracy function with lengthening of the

delay interval, as might have been predicted from prior data.

The animals were often observed through a one-way glass window in the ceiling of the experimental box. The subjects were not visible during the delay intervals (blackouts). Nevertheless, when the houselight and key lights came on again after a blackout, the birds were consistently observed to be poised in front of the correct key. This observation suggests that the birds bridged the gap between trials by orienting themselves in front of the "correct" key. Trials occasionally occurred on which birds did not even bend down to obtain the available grain reinforcements; instead, after a correct response, they immediately shifted to a position in front of the other key, which would be correct on the next trial.

The four birds which were next tested at delay intervals of 1, 3, 5, and 10 sec all showed

(Fig. 2) appreciable declines in accuracy at the 10-sec value, compared with the greater accuracy at the shorter delays; the figures contain plots of the mean "per cent correct" values for the last 10 days on this procedure. Two of the four subjects (No. 21 and No. 95) showed lower accuracy on 1-sec delays than on 3- and 5-sec delays, whereas the other two birds (No. 20 and No. 25) were equally accurate on 1- and 3-sec delays. In Fig. 1, where the delays tested ranged up to only 5 sec, all four birds had displayed the lowest accuracy at delays of 1 sec.

DISCUSSION

No evidence of an inverse, monotonic relation between delayed-alternation accuracy and delay interval was found in this experiment. Most of the individual functions of Fig. 1 indicated maximum accuracy at the in-

Fig. 2. Response accuracy as a function of delay interval for four subjects tested with delays of 1, 3, 5, and 10 sec.

intermediate delay intervals (2 or 3 sec) and minimum accuracy at the extreme delay intervals (1 and 5 sec). For delay durations of 1 to 10 sec, the data of Fig. 2 exhibited the same trend for two subjects; *i.e.*, No. 21 and No. 95 tended to be most accurate at 3 and 5 sec and least accurate at 1 and 10 sec. Studies of other kinds of delayed response (*e.g.*, Hunter, 1913; Blough, 1959) would suggest that a continuously decreasing function, or possibly a relatively horizontal function without a maximum, might be expected when response accuracy is plotted against delays from 1 to 10 sec.

Several procedural details may be noted which could have been at least partially responsible for this somewhat puzzling finding. Here, the bird's own behavior, rather than some externally programmed contingency (*e.g.*, as in Blough's delayed-matching procedure), produced the delay interval (blackout). Therefore, the amount of time out produced by key pecking might be expected to affect the accuracy of key pecking. A time out from positive reinforcement has been used as a mild punishment in several prior studies (*e.g.*, Ferster, 1958). The relatively minor aversive effects of a very short time out (*i.e.*, 1 sec) may be insufficient to appreciably suppress incorrect responding.

The findings of Ferster and Appel (1961) may be interpreted in a similar way. Those experimenters found that accuracy in a matching-to-sample task was greater when incorrect responses produced relatively long time outs (*e.g.*, 10-60 sec) than when they produced very short time outs (1 sec or less). Further evidence for this interpretation is the observation here that an immediate-correction procedure produced only chance accuracy (see footnote 2); an incorrect response may not be sufficiently punished in the immediate-correction procedure for it to be appreciably depressed. Early studies in which increased accuracy in discrimination problems occurred when incorrect responses were punished with electric shock may be examples of the same sort of effect; there, too, intermediate, rather

than low amounts of punishment, often produced the quickest learning and the greatest accuracy (Young, 1936).

This argument suggests that relationships between delay interval and response accuracy in the delayed-alternation task should not be considered as due exclusively to "memory" or "trace" variables. The aversive consequences of incorrect responding, *viz.*, the amount of time out produced, should be considered as a possibly confounding factor.

Most of the birds studied on this delayed-response technique showed greater accuracy at delays of 3 to 10 sec than did the birds Blough (1959) studied on his delayed-matching procedure. This may be due to the greater likelihood here that birds would acquire a mediating chain of responses which maximized reinforcements, *i.e.*, a key-peck was followed in all subjects by a postural orientation toward the key which would be correct on the next trial. In Blough's delayed-matching procedure, such a simple postural orientation was not possible. The stereotyped movements ("superstitions") that Blough often observed during the delay interval were probably more difficult to acquire than the simple position orientations of my birds, even though both kinds of mediating response may have served more or less the same function.

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