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DISCRETE-TRIALS SPACED RESPONDING IN THE PIGEON: THE DEPENDENCE OF EFFICIENT PERFORMANCE ON THE AVAILABILITY OF A STIMULUS FOR COLLATERAL PECKING[1]

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Four pigeons were exposed to a discrete-trial schedule in which only responses spaced by at least 6 sec were reinforced. After 45, fifty-trial sessions, they failed to meet the spacing requirement in over 90% of the trials. When an alternative, non-contingent key (pecks on which had no consequence) was illuminated concurrently with the first key, the spacing performance of the three pigeons that pecked the non-contingent key improved so that they were obtaining 75% of the possible reinforcers. These data demonstrated the importance of collateral behavior in mediating spaced performance. It was suggested that pigeons may successfully refrain from responding on the spacing procedure only when another stimulus correlated with reinforcement is available for pecking, and that the form that collateral behavior takes may, in general, be non-arbitrary, and species dependent.

In their comprehensive review of the behavioral effects of schedules that differentially reinforce spaced responding, or long interresponse times (DRL schedules), Kramer and Rilling (1970) pointed out that pigeons are "decidedly inferior" to rats, monkeys, and humans in terms of the percentage of reinforced responses they emit. Indeed, pigeons show relatively little systematic change in response probability as a function of time since the last peck even though the availability of reinforcement is conditional upon this duration. Thus, Reynolds (1964) found that pigeons on DRL 20-sec schedules developed stable performances characterized by relatively constant conditional probability of occurrence of interresponse times (IRT per opportunity, IRT/op) of durations greater than 5 sec. Moreover, the IRT/op distributions after 119 sessions were essentially the same as the distributions after six sessions. Similarly, Reynolds and Catania (1961) found that after 100 sessions on DRL 21-sec, the relative frequency of an IRT was a negative exponential function of IRT class, implying that responding was essentially random with respect to time. Results of this sort are particularly surprising in light of a number of demonstrations that pigeons can discriminate intervals of time (Reynolds, 1966; Reynolds and Catania, 1962; Stubbs, 1968). Apparently, the relatively poor performance of pigeons on DRL schedules does not arise simply because pigeons are insensitive to the passage of time. Rather, it is possible that pigeons' poor DRL performance reflects a lack of control by the response-constraining contingency, that is, an ineffectiveness of contingent non-reinforcement in suppressing premature key pecking. If so, the source of poor DRL performance may be related to the source of poor performance in the "negative" auto-maintenance phenomenon reported by Williams and Williams (1969); they found that pecking at a response key that was illuminated briefly before feeder operation was maintained even though key pecks prevented reinforcement. The failure of contingent non-reinforcement to suppress pecking in their situation cannot be attributed to faulty temporal discrimination because none was required.

There are, of course, many procedural differences between DRL and the procedure studied by Williams and Williams. Thus, the critical durations in DRL schedules are typically longer than the 6-sec trial duration used in the auto-maintenance work, and, perhaps more important, autoshaping typically involves a discrete-trials procedure, while DRL does not. While it seems plausible to consider

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similarities between DRL performance and auto-maintenance in pigeons, the lack of comparability between procedures makes such an undertaking highly conjectural. The present study was undertaken to provide a firmer basis for comparison between auto-maintenance and DRL performance. As in the earlier work on auto-maintenance, a discrete-trials procedure was used with an interval of 6 sec between trial onset and the availability of reinforcement. As in DRL, a response was required for the occurrence of reinforcement and the trial ended in non-reinforcement if the response was emitted in less than the criterion time of 6 sec. This procedure was developed to bring out most clearly possible relationships between auto-maintenance and DRL responding in pigeons.

METHOD

Subjects

Four naive Silver King pigeons (2247, 1604, 2139, 1198) were maintained at about 80% of their free-feeding weights.

Apparatus

One wall of a standard pigeon chamber contained a three-key pigeon panel with keys that could be illuminated by various colored lights. The keys were about 8 in. (20 cm) above the floor of the chamber, and about 4 in. (10 cm) apart, center-to-center. A food magazine was centered 5 in. (12.5 cm) below the center key. A deflector was placed on the houselight, located 3 in. (7.5 cm) above the center key, so that the light was directed toward the ceiling of the chamber.

Procedure

The pigeons were first trained to eat from the food magazine, and then exposed to a positive autoshaping procedure (Brown and Jenkins, 1968). The response key was periodically illuminated with green light for 6-sec periods, and followed by feeder operation, for 4 sec. A peck on the illuminated key immediately turned off the keylight, and produced the reinforcer. All the pigeons began pecking the key within 100 keylight-food pairings. The procedure was continued until each of the pigeons had pecked on at least 80% of the pairings for two consecutive sessions. After this criterion had been met, a DRL 6-sec discrete-trials procedure was initiated. The center key was periodically illuminated with a green light. If the pigeon pecked before the 6 sec had elapsed, the stimulus went off, terminating the trial without reinforcement. If no peck occurred for 6 sec, the first peck turned off the stimulus and was reinforced. The pigeons were exposed to 45 daily sessions of this procedure, each session consisting of 50 trials. Trials were separated by an intertrial interval of 10 to 90 sec, with a mean of 30 sec.

For the next 18 sessions, the DRL continued as before, but on each trial, the left side key was illuminated with blue light, whenever the center key was illuminated. The two keys were darkened simultaneously at the end of each trial. Pecks on the left key (the non-contingent key) had no scheduled consequence. This procedure is analogous to the Williams and Williams (1969) "irrelevant key" procedure, which substantially improved performance on negative auto-maintenance.

During the sixty-fourth session, the left key was never illuminated. During the next five sessions, it was presented on a random half of the trials, and not illuminated on the other half. After 69 sessions, the experiment terminated.

RESULTS

Figure 1 presents latency distributions for the individual pigeons on the third and forty-fifth sessions of DRL. In Session 3, Pigeon 2247 obtained six reinforcers, 1604 obtained two, 2139 obtained four, and 1198 obtained three. The modes of the latency distributions were under 2 sec for all but one pigeon (2247), where the mode was at 3 sec. By session 45, more than 2000 trials later, only the performance of Pigeon 1604 had improved. The mode of its latency distribution was at 5 sec, and it obtained seven reinforcers. The performance of the other three pigeons was, if anything, poorer in Session 45 than in Session 3: as a group, these birds obtained only 4% of the possible reinforcers.

All pigeons began pecking the non-contingent key during the session in which it was first introduced. With the exception of Pigeon 2139, which rarely pecked the non-contingent key, the amount of pecking on the non-contingent key, and the number of DRL reinforcements, increased gradually until stable performance was reached at about the ninth

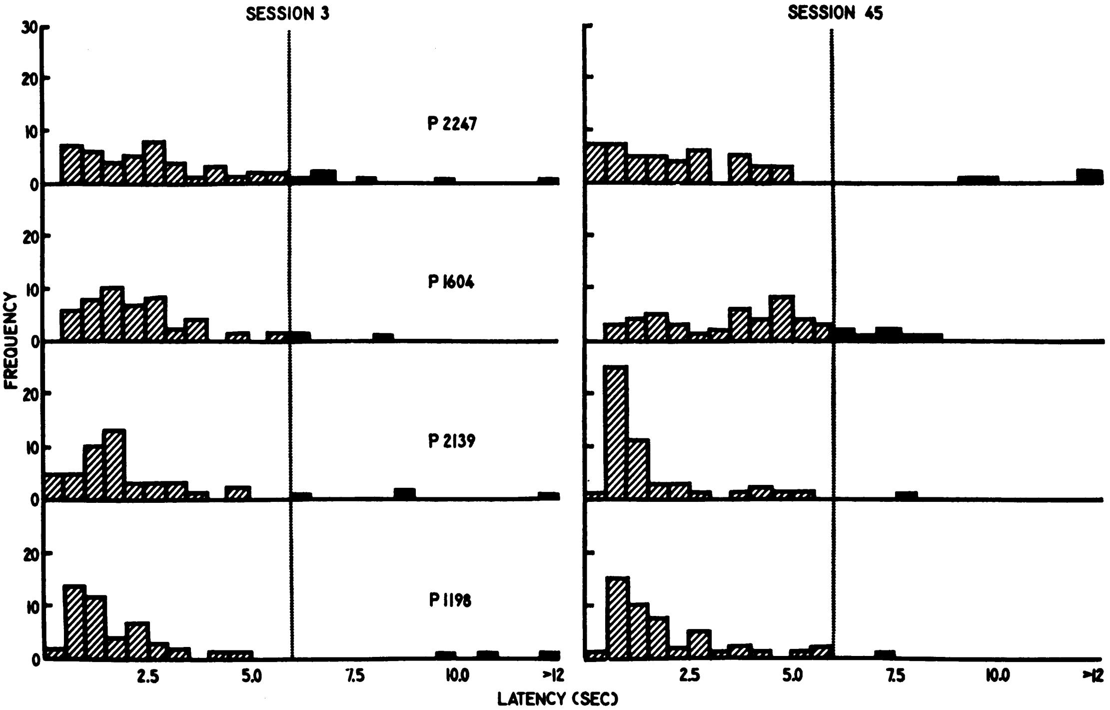

Fig. 1. Latency distributions for the individual pigeons in Session 3 (left) and Session 45 (right) of the DRL. Latencies are divided into 0.5-sec class intervals. All latencies represented by filled bars were reinforced.

session. Figure 2 shows individual latency distributions in the eighteenth session after the non-contingent key was introduced. With the exception of Pigeon 2139, the latency distributions now peaked at between 6 and 8 sec, and the pigeons obtained more than 70% of the possible reinforcers. In the session shown, Pigeon 2247 made 649 responses, 1604 made 604 responses, 2139 made 54 responses, and 1198 made 775 responses on the non-contingent key. All pigeons except 2139 pecked the non-contingent key on almost every trial, and distributed their pecks on this key fairly evenly throughout the trial. Figure 3 presents sample event records from the session where latencies are shown in Fig. 2. The record of Pigeon 1198 is representative of the records of Pigeons 2247 and 1604, and obviously different from the record of Pigeon 2139.

Figure 4 presents the latency distributions from the session in which the non-contingent key was removed, which immediately followed the session shown in Fig. 2. Comparison of this figure with Fig. 2 shows that the improved performance that developed after introduction of the non-contingent key was dependent on the continued availability of the key, and did not transfer to the single-key situation. This fact is demonstrated most clearly in the distributions of Fig. 5, taken from the first session in which the non-contingent key was presented on only half of the trials. It can be seen that, with the exception of Pigeon 2139, there was essentially no overlap in the distributions from trials with the non-contingent key and trials without it. Pigeons 2247, 1604, and 1198 obtained a combined total of one reinforcer of a possible 75 when the non-contingent key was absent, and 64 of 75 when it was present. Performance in the next four sessions on this procedure was substantially the same for all pigeons.

DISCUSSION

The present procedure and results both have obvious counterparts in the work on auto-maintenance reported by Williams and Williams (1969). Procedurally, both studies constrained responding for a fixed 6-sec period. In both cases this constraint was only infrequently met: all birds pecked prematurely on a substantial number of trials, and thereby prevented reinforcement. Under both

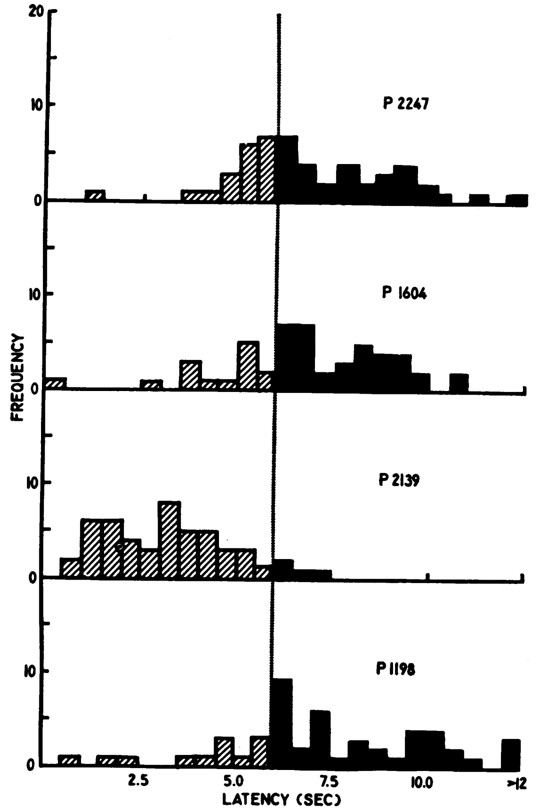

Fig. 2. Latency distributions for the individual pigeons in Session 18 of the DRL non-contingent key procedure. See Fig. 1 for details.

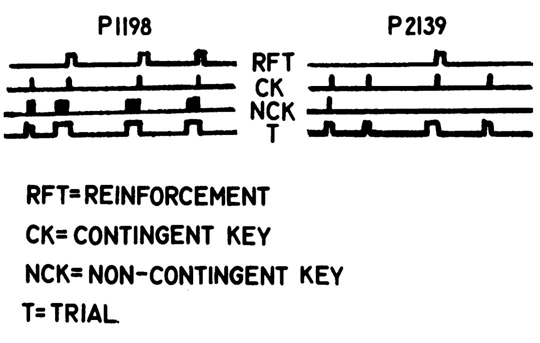

Fig. 3. Event records for Pigeons 2139 and 1198 from Session 18 of the DRL non-contingent key procedure. The records read from left to right. Deflections upwards from the baselines indicate events. The four lines represent (from the bottom up) the duration of the DRL trials, the non-contingent key pecks, the DRL peck that terminated the trial, and reinforcement. The spaces between upward deflections of the bottom line represent intertrial intervals.

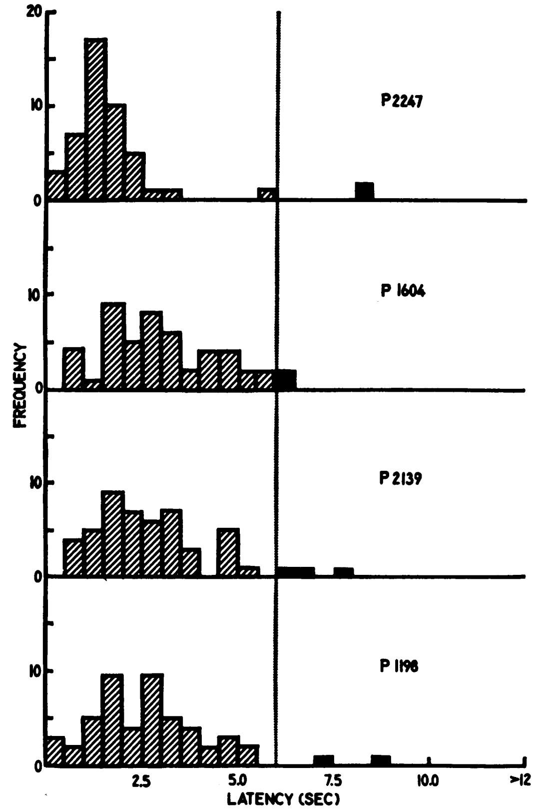

Fig. 4. Latency distributions for the individual pigeons in the session of DRL that followed the 18 DRL non-contingent key sessions. See Fig. 1 for details.

procedures, the introduction of a second key, on which there was no effective contingency, contributed significantly to the development of control by the response-constraining contingency that was in effect on the original key. In the present DRL study, the demonstration of control by the response-constraining contingency included a demonstration of sensitivity to some aspect of the trial duration, that is, under this condition, pigeons showed clear evidence of "temporal discrimination".

The importance of collateral behavior to the development of effective DRL performance by pigeons indicates either (a) that collateral behavior is central to timing or (b) that collateral behavior is essential to the operation of the response-constraining contingency on DRL. Although it is not possible to select between these alternatives on the basis of the present experiment alone, when these results are considered along with those of Williams and Williams on negative auto-maintenance,

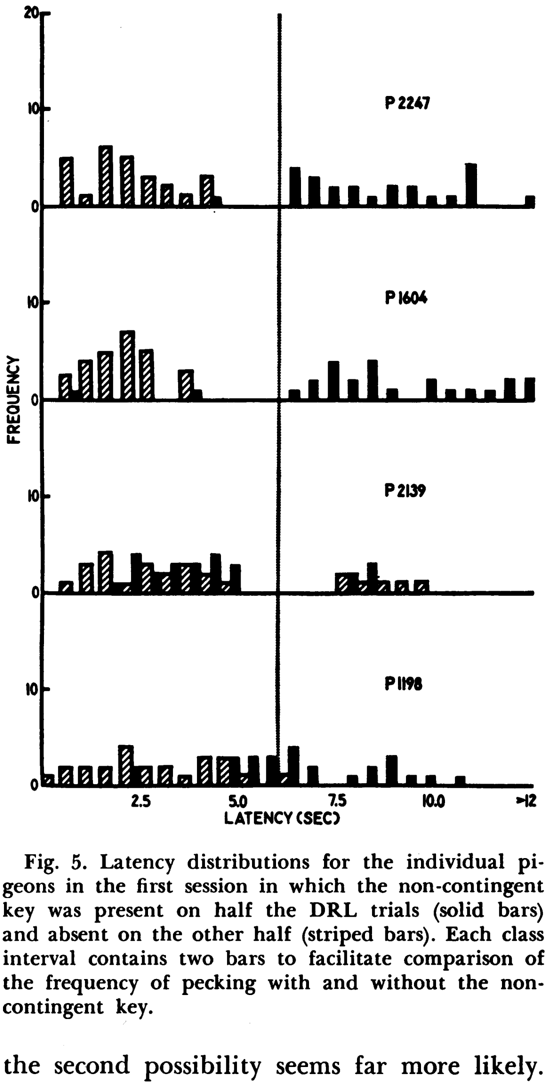

Fig. 5. Latency distributions for the individual pigeons in the first session in which the non-contingent key was present on half the DRL trials (solid bars) and absent on the other half (striped bars). Each class interval contains two bars to facilitate comparison of the frequency of pecking with and without the non-contingent key.

the second possibility seems far more likely. Under conditions of auto-maintenance there is no obvious involvement of a temporal discrimination: reinforcement depends only on refraining from pecking a response key *whenever* it is illuminated. It would be gratuitous to invoke the notion of temporal discrimination under those conditions, and it seems equally unnecessary in the present experiment. It appears more straightforward to conclude that the poor performance of pigeons on DRL schedules is due to an ineffectiveness of the response-constraining contingency. In drawing this conclusion we do not deny that collateral behavior plays a role in supporting "temporal" stimulus control as well. We concur with the suggestion of Laties, Weiss and Weiss (1969) that "the precise stimulus function of each example of collateral behavior be established independently." Whether or not particular instances of collateral behavior enter into timing, however, an essential contribution of collateral key pecking in the present experiment (as in the auto-maintenance procedure) would appear to be its role in establishing the effectiveness of the response-constraining contingency.

The fact that pecking is involved in operant, collateral, and consummatory behavior complicates both an analysis of the important relationships in the present situation and cross-species comparisons. Some clarification of this difficulty is contributed by a study of Hemmes (1970), which shows that pigeons performed far more efficiently on a DRL 14-sec when treadle-hopping was the operant than when key pecking was the operant (5.0 *vs.* 18.5 responses per reinforcement, respectively) even when no explicit stimulus for collateral behavior was provided. Hemmes' study suggests that the use of key pecking as the operant response is a major source of difficulty. Williams and Williams' work on negative autoshaping indicates that the key-pecking response may be non-arbitrary in the sense that it is controlled by factors other than the outcomes it produces. The possibility that key pecking on DRL can be controlled by factors other than its consequences is consistent with the hypothesis that the response-constraining contingency on DRL is relatively ineffective in the typical situation involving a key-pecking "operant" in pigeons.

It is also noteworthy that effective collateral behavior took the form of pecking a non-contingent key presented along with the DRL key. Other apparently possible forms of effective collateral behavior, such as turning away from the key, or pecking at the houselight, did not develop. This finding is also in close agreement with the results of Williams and Williams. On the hypothesis that key pecking is not "arbitrary", in the sense of depending solely on its consequences, it seems reasonable to suspect that there may be corresponding restrictions on the kinds of collateral behavior that can successfully compete with the key-pecking response. Although a detailed understanding of the varied sources of control of behavior (for example, consequences, and factors that contribute to auto-maintenance) and their interaction has not yet been reached, results of the sort obtained in this study and by Williams and Williams point clearly to the necessity for experimental analysis of this problem. On the basis of the present results, however, it seems clear that the relatively poor performance of pigeons on DRL schedules arises because the normal DRL situation does not permit the development of collateral behaviors that would make the response-constraining contingency effective for an operant that is not entirely arbitrary. It is noteworthy, in this regard, that McMillan (1969) and Zuriff (1969) found that *operant* key pecking constituted effective collateral behavior for pigeons on DRL schedules.

It is interesting that in rats, effective collateral behavior frequently takes the form of oral behavior even when a number of different response opportunities is offered. The most striking demonstration of this phenomenon was reported by Laties *et al.* (1969). Though an alley was attached to a standard rat chamber to permit "mediation" of the DRL by running, and though the rats actually did traverse the runway early in their exposure to the DRL schedule, all animals finally developed the behavior of gnawing on various parts of the apparatus, as did control rats that had not had access to the runway. Furthermore, Laties *et al.* were able to demonstrate that the collateral behavior of gnawing contributed to effective DRL performance. It is interesting that gnawing—which in all likelihood is a non-arbitrary response in a feeding situation for rats—predominated over the arbitrary operant of running in this study (see also, Breland and Breland, 1961). Whether the contribution of gnawing to the DRL performance of Laties *et al.* rats arose through a contribution to control by the response-constraining contingency or through some other contribution is not clearly established. What is important, however, is the point that rats appear to have available non-arbitrary responses in the standard experimental situation other than the "operant" itself. It would appear that pigeons do not, and this factor may well be critical in accounting for the relatively poorer performance of pigeons under standard DRL conditions.

The circumstances under which collateral behavior contributes to the development of effective control by response-constraining contingencies and the involvement of non-arbitrary relations among operant, collateral, and consummatory behavior are matters for further experimental analysis. Our hypothesis regarding the relative difficulty of establishing efficient DRL performance in pigeons suggests that, as Bolles (1970) also suggested in connection with efficient avoidance learning, the most critical feature of the DRL situation is the interaction between what the organism brings to it in terms of species-specific behaviors and what opportunities the experimental space provides in terms of possibilities for expression of those behaviors.

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