

SPACED-TRIAL OPERANT LEARNING WITH PURELY INSTRUMENTAL CONTINGENCIES IN PIGEONS (*COLUMBA LIVIA*)

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ABSTRACT: The purpose of this experiment was to study persistence during extinction of key pecking performance in pigeons (*Columba livia*) after training with either a large (15 food pellets) or a small reward magnitude (1 food pellet). Strictly instrumental contingencies were enforced and a single trial per daily session was administered. There were 52 acquisition trials followed by 48 extinction trials. Although extinction started from similar response levels in both groups, the pigeons trained with 15 pellets exhibited significantly slower extinction than those trained with a single pellet. This result is discussed in the context of comparative research on the effects of reward magnitude and schedule on extinction in vertebrates.

Pigeons can be trained to peck at a key for either a small (1 pellet) or a large reward (10 or 15 pellets, depending on the experiment) when practice is administered at a rate of a single trial per daily session (Papini, 1997). The main outcome of a series of experiments based on such a procedure was that extinction of key pecking was faster after acquisition with the small reward, rather than with the large reward. This type of behavioral adjustment to extinction is referred to as nonparadoxical performance. Such a result is interesting from the comparative point of view because nonparadoxical performance is typical of fish, amphibians, and reptiles, but not of mammals trained under analogous conditions (Bitterman, 1975). Mammals show paradoxical performance, that is, the successive negative contrast effect and the magnitude of reinforcement extinction effect (Amsel, 1992; Bitterman, 1975), under analogous training conditions (i.e., spaced-trial training with different reward magnitudes). In the case of contrast,

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mammals shifted from a larger or more preferred reinforcer to a smaller or less preferred one exhibit a deterioration of instrumental performance beyond the level of a control group always trained with the smaller or less preferred reinforcer. In the case of the magnitude effect, extinction is faster after training with a larger reinforcer, than after training with a smaller one. These results are paradoxical in the sense that they are not predicted by classic theories based on the hypothesis that associative strength is a direct function of reinforcer magnitude (Amsel, 1992).

The key-pecking experiments with pigeons have involved a relatively wide range of conditions; still, the results may depend upon some aspect of the training procedure, rather than on the species. For example, Roberts, Bullock, and Bitterman (1963) reported greater resistance to extinction after widely spaced training with partial reinforcement than with continuous reinforcement, a paradoxical effect thought to be related to contrast (Amsel, 1992). One major difference between Roberts et al.'s study and Papini's experiments is found in the nature of the reinforcement contingencies involved in each case. Roberts et al. used a runway procedure in which pigeons either responded in every trial, or were gently guided toward the goal box if they failed to initiate a response. As a result, the outcome of each particular trial was preceded by running, the target response in the experiment. By contrast, the operant procedure imposed a time limit for key-pecking, so that if the pigeon failed to respond within that interval, the scheduled outcome occurred and the trial was terminated. Although Papini (1997) showed that relatively few acquisition trials ended without the occurrence of key-pecking (the target response), this procedure introduces a response-independent outcome component that could have caused nonparadoxical extinction performance.

In the present experiment, a series of 10 key-pecks were paired with either 1 pellet or 15 pellets in independent groups during acquisition training. Failure to complete the fixed-ratio (FR) 10 requirement within a maximum time resulted in the termination of the trial and the withholding of the reward. This procedure is therefore referred to as purely instrumental in the sense that the reinforcing event only occurred when the animal satisfied the response requirement within a time limit.

METHOD

Subjects

Twelve pigeons, all sexually mature and obtained from a local dealer, served as subjects. Animals were housed in individual wire cages. Water and grit were continuously available in the cage, but food was restricted to keep animals at 75% of their ad libitum weights. The colony room was continuously illuminated. These pigeons had received previous training under similar conditions (see Papini, 1997, Experiments 1 and 3). Their previous experience involved training with 1 ($n = 5$) or 15 pellets ($n = 7$); the prior magnitude assignment was kept constant in the present experiment, in which the same reward magnitudes were used.

Apparatus

Training was administered in three boxes equipped with a single pigeon key and a pellet dispenser. Each box was enclosed in a sound-attenuating chamber containing a fan for ventilation and masking background noise. Boxes were 32.2 cm wide, 29.9 cm long, and 32.2 cm high. A feeder cup made of opaque Plexiglas and measuring 4.5 cm wide, 5.5 cm long, and 4 cm high was located in the center of one of the walls, 3 cm above the floor. Noyes precision pellets (pigeon formula, 45 mg) were automatically delivered into this cup by the pellet dispenser. Directly above the feeder cup and 18.5 cm from the floor was the response key (1.8 cm in diameter). This key could be illuminated from behind with a variety of stimuli. A white key was used during pretraining sessions, whereas a white "plus" sign on a black background was used during acquisition and extinction. Diffuse illumination was provided by a lamp (GE 1820) located on the upper left corner of the same wall. A computer located in an adjacent room controlled all the events and recorded response latencies.

Procedure

The present experiment introduced a purely instrumental response-reinforcer contingency both in pretraining and training. Therefore, reinforcement was provided only whenever the response requirement valid for a particular trial was met within a certain temporal window; otherwise, the trial ended without the delivery of

food.

Approximately 20 days after the end of the previous experiment, pigeons were returned to pretraining. Each pretraining session involved 20 trials separated by a mean intertrial interval of 60 s (range: 40-80 s). All pigeons received the same reward magnitude (i.e., 1 pellet per trial) during pretraining. These animals had been exposed to extinction at the end of the previous experiment (Papini, 1997) and, thus, the key-pecking response had to be reshaped. Pretraining started with exposure to a procedure involving both Pavlovian and instrumental contingencies. In each trial, the white key-light was presented for a maximum of 6 s. After either a single key-peck response or 6 s, whichever occurred first, the key-light was turned off and a single food pellet was immediately delivered in the food cup. When a pigeon reached a criterion of two successive sessions with a probability of response equal to or greater than 0.8 (i.e., at least 16 out of 20 trials with a response), the Pavlovian component was eliminated and pretraining continued in a purely instrumental manner. The white key-light was presented for a maximum of 6 s and a single response during that interval turned off the key-light and caused the delivery of a food pellet; failure to respond within the 6 s interval terminated the trial without reinforcement. Pigeons were trained on this FR 1 schedule until the probability of response on two consecutive sessions was equal to or greater than 0.8, whereupon the FR requirement was increased by one response. This criterion was kept constant until pigeons reached a FR 10 value; in this final stage, pigeons were trained for a minimum of 5 sessions and until they met a criterion of 3 consecutive sessions with a probability of response equal or greater than 0.8. Starting with a FR 2 value, there was a maximum of 15 s to initiate responding, and a maximum of 15 s to complete the FR requirement once responding had been initiated. Failure to initiate responding or to complete the FR once responding had been initiated was followed by key-light offset; no reinforcement was delivered.

Acquisition training began the day after pigeons met the FR 10 criterion and lasted for 52 daily sessions. Each session involved a single trial. Pigeons were transported from the vivarium to the training room in their individual cages and were placed in the conditioning boxes. The start of the session was signaled by the illumination of the box. After a mean pretrial interval of 60 s (range: 30-90 s), the "plus" sign was projected onto the response key. Completion of the FR 10 requirement resulted in the immediate delivery of either 1 pellet (Group 1) or 15 pellets (Group 15). The 15 pellets were delivered in rapid

succession, at a rate of one pellet every 20 msec. Pigeons had a maximum of 60 s to initiate responding and a maximum of 60 s to complete the 10 required responses. Failure to initiate responding or to complete the FR 10 requirement within 60 s terminated the trial without reinforcement. The daily session ended with a mean post-trial interval of 60 s (range: 30-90 s), at the end of which the house light was turned off and the animal was returned to its cage. Following acquisition, there were 48 extinction sessions that were equal in all respects to acquisition sessions except that food pellets were not delivered.

A computer recorded the initial latency, or time from the onset of the key-light to the first key-peck response, and the FR latency, or time from the first to the tenth key-peck. A maximum value of 60 was assigned to both initial and FR latencies when the pigeon failed to respond in any given trial. Absolute time values were transformed to their natural logarithm (\ln) to improve normality and allow for the use of parametric statistics. Transformed latencies were pooled over blocks of 4 trials for each animal and subjected to mixed-design analysis of variance.

RESULTS

Four pigeons failed to reach the FR 10 criterion during pretraining, presumably due to the purely instrumental contingency introduced in the present experiment. Although the conditions during pretraining were not differential, these pigeons had already been assigned to the groups based on their prior experience (one to Group 1 and three to Group 15). These animals were discarded and acquisition training (one trial per day) was conducted with the remaining 8 pigeons, 4 in each group.

The main results of the present experiment are presented in Figure 1 in terms of the \ln of the initial latency (left) or FR latency (right), for Groups 1 and 15, and as a function of 4-trial blocks. Initial acquisition latencies were relatively low because these animals had been previously trained to respond to the plus stimulus. Both latency measures were higher for Group 1 than for Group 15 early in acquisition training, but they rapidly converged. Group \times Block analyses of variance for each dependent measure indicated nonsignificant effects for Group [both $F(1, 6) < 4.09, p > .05$], Block [both $F(12, 72) < 1.02, p > .05$], or their interaction [both $F(12, 72) < 1.48, p > 0.05$]. However, a similar analysis over the initial 5 blocks of training detected a significant

Group effect for the FR latency [$F(1, 6) = 9.12, p < 0.025$].

Extinction performance was highly differential after acquisition training with either 1 or 15 food pellets. In fact, both initial and FR latencies showed very little decrement, if any, after training with the large, 15-pellet reward magnitude during a string of 48 daily trials. Analyses of variance computed for each dependent variable confirmed these conclusions. In the case of the initial latency, there were highly significant effects for Group [$F(1, 6) = 39.15, p < 0.001$], Block [$F(11, 66) = 4.08, p < 0.001$], and for the Group \times Block interaction [$F(11, 66) = 2.60, p < 0.001$]. Similarly, the FR latency measure also yielded highly significant effects for Group [$F(1, 6) = 80.93, p < 0.001$], Block [$F(11, 66) = 3.42, p < 0.001$], and their interaction [$F(11, 66) = 4.00, p < 0.001$].

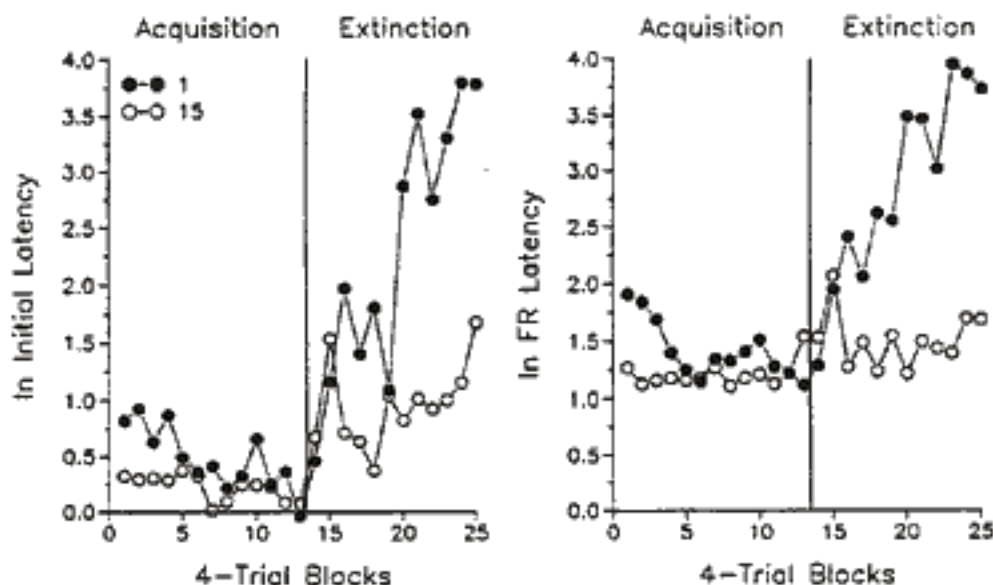


Figure 1. Acquisition and extinction of key pecking in groups of pigeons reinforced with either 1 or 15 food pellets. Initial (left panel) and fixed-ratio (FR) latencies (right panel) were transformed to natural logs and plotted as a function of 4-trial blocks. Each point represents the arithmetic mean of four subjects in each group.

Additional information was obtained from the trials in which pigeons either initiated but did not complete the FR requirement (incomplete FR), and trials in which animals did not respond at all (response failure). These results are presented in Table 1.

In the 52 acquisition trials, there were relatively few instances of incomplete FR trials, but a few more cases of response failure, although all of them in Group 1. Although not particularly strong, the evidence presented in Table 1 suggests that acquisition performance was facilitated by the larger magnitude of reinforcement under the present, purely instrumental, conditions. In the 48 extinction trials, there were clearly more instances of both incomplete FR trials and response failures in Group 1 than in Group 15. Generally, these data suggest that the effects of reinforcer magnitude on key-pecking performance are predominantly reflected in terms of response failure. Once pigeons initiate responding in any given trial, they are likely to complete the FR requirement.

Table 1. Number of trials in which pigeons failed to respond or initiated but did not complete the FR requirement. Number in parenthesis corresponds to the range for each group of four animals.

	Incomplete FR		Response Failure	
	Acquisition	Extinction	Acquisition	Extinction
Group 15	0.50 (0-1)	0.25 (0-1)	0	3.00 (0-5)
Group 1	0.25 (0-1)	2.75 (1-5)	1.50 (0-4)	20.75 (19-23)

DISCUSSION

The degree of persistence during extinction observed in pigeons trained with the large reward was remarkable. This type of persistence is typical of mammals trained under small reward conditions or of infant rats (Amsel, 1992), but not of adult rats trained under widely spaced conditions with relatively large reward magnitudes (Hulse, 1958; Wagner, 1961). These results agree with those previously reported by Papini (1997) and suggest that the emergence of nonparadoxical extinction performance is not related to the presence of a response-independent component in the reinforcement contingency implemented in the original experiments. Persistence is greater after large rewards than after small rewards whether extinction of key pecking follows training under a purely instrumental contingency (present experiment) or under a mixed instrumental and Pavlovian

contingency (Papini, 1997).

The results reported by Roberts et al. (1963), using a runway procedure, can be interpreted as inconsistent with the present data. These findings are contradictory to the extent that extinction after manipulations of reinforcer schedule and magnitude are thought to depend on the same mechanisms (Amsel, 1992). It is possible that, in the pigeon, whether extinction is paradoxical (as in Roberts *et al.*'s study) or not (as in the present study) might depend on the response system used to assess instrumental learning (i.e., key-pecking versus running responses). Although there is limited information on this issue in mammals, the operant-instrumental distinction does not appear relevant. McNaughton (1984) compared lever pressing (operant) and runway (instrumental) performance of rats given a single trial per day, finding clear evidence of the partial reinforcement extinction effect in both situations. A clarification of the role of response bias in the paradoxical performance of pigeons will require a study of the effect of partial reinforcement on extinction of key-pecking performance, as well as the effect of reward magnitude on extinction of runway performance, both under spaced-trial conditions.

Key-pecking behavior acquired by pigeons under widely temporally spaced conditions of training appears to depend entirely upon the associative strength gained by the stimulus through its pairing with rewards of various magnitudes (Bitterman, 1975). Such a simple assumption has proven inappropriate for handling the results obtained with mammals (Amsel, 1992; Daly & Daly, 1982). Further analysis of learning in a comparative framework will contribute to establishing the limits of behavioral processes thought to be general, such as the acquisition of anticipatory frustration (Amsel, 1992) or of specific reward memories (Capaldi, 1994). Although hypothetical general processes have been helpful for understanding some aspects of learning in mammals, they do not seem to be required to explain available evidence from spaced-trial experiments with a variety of non-mammalian vertebrates.

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