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AUTO-MAINTENANCE IN THE PIGEON: SUSTAINED PECKING DESPITE CONTINGENT NON-REINFORCEMENT[1]

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If a response key is regularly illuminated for several seconds before food is presented, pigeons will peck it after a moderate number of pairings; this "auto-shaping" procedure of Brown and Jenkins (1968) was explored further in the present series of four experiments. The first showed that pecking was maintained even when pecks turned off the key and prevented reinforcement (auto-maintenance); the second controlled for possible effects of generalization and stimulus change. Two other experiments explored procedures that manipulated the tendency to peck the negatively correlated key by introducing alternative response keys which had no scheduled consequences. The results indicate that pecking can be established and maintained by certain stimulus-reinforcer relationships, independent of explicit or adventitious contingencies between response and reinforcer.

Brown and Jenkins (1968) reported a method for automatically and rapidly establishing key pecking in pigeons. Although their "shaping" procedure was carried out without reference to the birds' behavior, it led uniformly to the development of key pecking. Brown and Jenkins suggested that adventitious reinforcement of key-orienting behavior, aided by a tendency for birds to peck at things they look at, might provide a full account of their findings. The consistent success of their procedure with a large number of subjects, however, suggests the operation of a more deterministic mechanism than one based primarily on adventitious reinforcement. The present experiments were carried out to explore the possibility that the auto-shaping procedure directly and actively engenders pecking.

The basic procedure of the present experiments was a variant of Brown and Jenkins' procedure in which pecks prevented reinforcement. As in their method, a response key was illuminated for several seconds before grain was presented. In the present experiment, key pecking turned off the key and blocked presentation of the reinforcer, so that pecking actually prevented the reinforcing event. Because the effect of key pecking under this procedure was not irrelevant to reinforcement but rather reduced it, persistent responding would raise a strong presumption that key pecking can be directly maintained by variables which do not involve response-reinforcer relationships of either deliberate or accidental origin.

EXPERIMENT I

METHOD

Subjects

Thirteen naive Silver King pigeons, deprived to 80% of their free-feeding weight, served.

Apparatus

The pigeon chamber was 13 by 13 by 12 in.; one wall housed a standard three-key Lehigh Valley pigeon panel with keys which could be transilluminated by colored lights and vertical and horizontal striped patterns. The houselight and the keys used #1829 bulbs operated at 20 v dc. The keys were 8.5 in. above the floor of the compartment, and the grain hopper was centered 5 in. below the middle key.

Procedure

Upon initial placement in the experimental space, an experimentally naive bird was confronted by a raised grain hopper filled to the

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top with grain. The bird was allowed to eat for about 20 sec, after which the hopper was withdrawn. Over the course of several further presentations, which took place without reference to the bird's behavior, eating time was reduced to 4 sec. After these initial unsignalled presentations, birds were either placed directly on the negative procedure or first treated as described in Table 1, and then placed on the negative procedure.

Table 1

Number of sessions during which the procedures indicated were in force; procedures to the left were carried out first.

Bird	*Hand-Shaping*	*Auto-Shaping*	*FR 1 Timeout*
P-16	1	0	1
P-17	0	2	1
P-18	0	4	2

Auto-shaping: positive response contingency. Trials consisted of a 6-sec illumination of the center key, after which the key and the houselight were turned off, and the hopper was presented for 4 sec. Trials were separated by an intertrial interval averaging 30 sec, and ranging from 3 to 180 sec. Each peck on the lighted key turned off the key and the houselight, and presented the feeder directly. Intertrial pecks were recorded but had no scheduled consequences.

Auto-shaping: negative response contingency. The negative auto-shaping procedure exactly duplicated the positive auto-shaping procedure described above, except on trials where the lighted key was pecked. On those trials, the peck turned off the key, but the grain hopper was not presented. Neither the intertrial interval nor the onset of the next trial was altered by a peck; the key was simply darkened and the grain hopper was not presented. Intertrial pecks had no scheduled consequences.

Hand-shaping. After the general pretraining trials, the magazine was presented 50 additional times without warning on each of two successive days. The times between presentations were similar to the intertrial intervals in the auto-shaping procedure, but the response key was never illuminated. On the third experimental day, the key was illuminated on a trials basis, as in the auto-shaping procedure. The key remained on until the reinforcer was presented according to the method of successive approximations described in Ferster and Skinner (1957). A total of 50 reinforcers was presented on this day.

FR 1 Timeout. Under this procedure, the key was illuminated for a 6-sec period, unless a peck occurred. If a peck occurred, the houselight and key light were turned off and the reinforcer was presented. If the key was not pecked, it was turned off and no reinforcer was presented. Intertrial intervals were the same as in the positive auto-shaping procedure.

RESULTS

Figure 1 shows results from four birds trained under auto-shaping with a negative response contingency. P-12 and P-19 received no prior training, whereas P-16 and P-17 had previously been trained on FR 1 Timeout. The ordinate of each panel represents the cumulative number of trials within each daily session on which a peck occurred, while the abscissa marks successive trials. A high slope indicated a high frequency of pecks on the negatively correlated key, and therefore a low frequency of reinforcement. Substantial responding clearly took place despite the negative correlation between pecking and reinforcement. Although P-12 did not begin pecking until 220 trials had been administered (and, therefore, 220 reinforcers presented), pecking was maintained at a remarkably high level for the next 18 days until another procedure (to be described in Exp. III) was instituted. Once pecking commenced, it persisted at a level such that only five to 20 reinforcers per day were presented out of a possible 50. P-19 began substantial pecking on the second day of training but did not maintain a high rate after Trial 150. Over the next 12 experimental sessions, pecking by this bird did not disappear but occurred only on a small percentage of the trials.

Because of prior training with a positive response contingency, P-16 and P-17 began the procedure with a high frequency of pecking. Over the first five sessions, the tendency of P-16 to peck decreased in a regular fashion. Some recovery took place after the fifth day, however, and substantial pecking continued throughout the next 15 days, waxing and waning over periods of several sessions. P-17 produced a similar overall pattern: during the

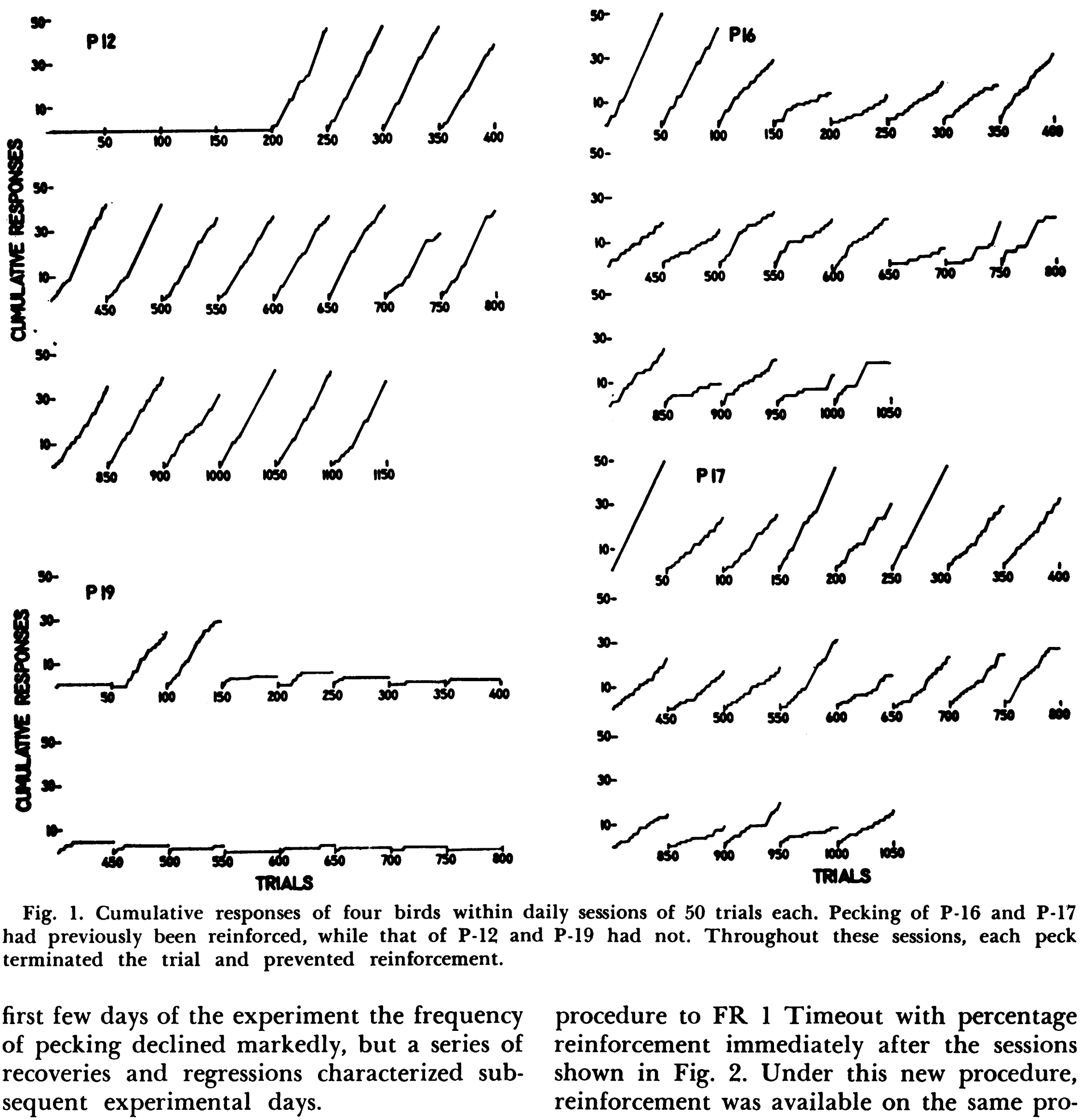

Fig. 1. Cumulative responses of four birds within daily sessions of 50 trials each. Pecking of P-16 and P-17 had previously been reinforced, while that of P-12 and P-19 had not. Throughout these sessions, each peck terminated the trial and prevented reinforcement.

first few days of the experiment the frequency of pecking declined markedly, but a series of recoveries and regressions characterized subsequent experimental days.

Results from the first 13 birds trained on auto-shaping with a negative response contingency are summarized in Fig. 2. It is evident that the procedure typically supported significant levels of responding whether or not key pecking had previously been reinforced (see Table 1 for particulars), and that the key pecking response could be established and maintained even though reinforcement was contingent on a failure to peck the key. Only one bird (P-19) regularly responded on less than 10% of the trials once pecking had begun.

The negative contingency was not wholly without effect. Two birds (P-019 and P-020) were changed from the negatively contingent procedure to FR 1 Timeout with percentage reinforcement immediately after the sessions shown in Fig. 2. Under this new procedure, reinforcement was available on the same proportion of trials as had actually included reinforcement on the final three days with the negative contingency. Latency distributions from the last three days of contingent nonreinforcement, and from the last three sessions under percentage reinforcement, are compared in Fig. 3. Two changes are evident: under percentage reinforcements, pecking took place on a greater proportion of trials than before, and the pecks were generally of shorter latency. The longer latencies that characterized the distributions under the negative procedure were also a conspicuous feature of latency distributions from other birds trained with the negative procedure.

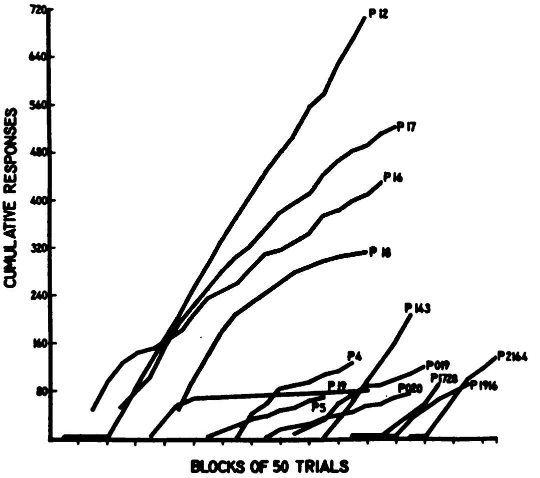

Fig. 2. Cumulative responses per session for the first 13 pigeons run with contingent non-reinforcement. Curves for the various birds are displaced along the abscissa.

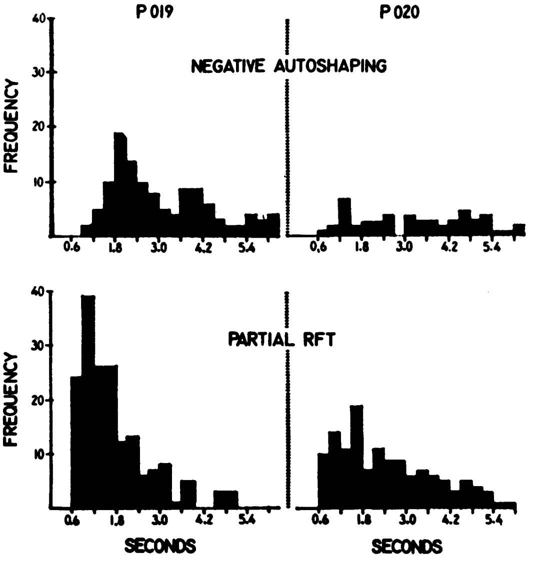

Fig. 3. Latency distributions for two birds (left and right columns) under contingent non-reinforcement and subsequent partial reinforcement. Latencies are indicated only for trials where pecks actually occurred.

EXPERIMENT II

The persistent pecking observed under the negative contingency might be attributed to generalization of feeder-oriented pecking or to reinforcement from stimulus change. A successive discrimination experiment carried out in a parametrically similar framework permitted assessment of these possibilities. On trials where the key was illuminated with the positive discriminative stimulus (S^D), a peck turned off the key and was reinforced; trials of this sort maintain feeding and feeder-oriented pecking in the situation. On trials where the other stimulus (S^Δ) was presented, no grain reinforcers could be produced but pecks did turn off the stimulus. Observation of pecking at S^Δ thus provided a means of assessing both the level of generalized pecking and the level of pecking maintained by the stimulus change itself. The main difference between discrimination training and auto-shaping with a negative contingency is that S^Δ is never paired with grain, but the negatively contingent key does receive such pairing on trials where pecks are not made. Differences between pecking S^Δ and pecking the negative key therefore indicate the effectiveness of the pairing procedure itself.

METHOD

Subjects

Six experimentally naive Silver King pigeons were deprived to 80% of their free-feeding weight.

Procedure

The apparatus and general procedures were identical to those described for Exp. I. Three birds (P-20, P-21, P-2) were trained initially by postitive auto-shaping, and three (P-7, P-8, P-9) by the hand-shaping procedure. After pecking commenced, all birds were trained on the FR 1 Timeout procedure for two days. Discrimination training was then introduced and consisted of 100 trials per day, of which half were positive and half were negative. The intertrial intervals were as in Exp. I. For birds P-7, P-8, and P-2 the discriminanda were red *vs.* green keys and for birds P-9, P-20, and P-21 they were horizontal *vs.* vertical stripes presented against a green background. On any trial the key was illuminated for 6 sec if no peck occurred. When a peck occurred, the key was turned off. On positive trials, 4-sec access to grain followed immediately, but no access to grain was provided on negative trials. The rate of trial presentation could not be influenced by pecking.

RESULTS AND DISCUSSION

Because all birds pecked on virtually every positive trial, those results are not presented. Figure 4 summarizes the data from S^Δ trials for all six birds, plotted on coordinates similar to those of Fig. 2 to facilitate comparison. Training was terminated for each bird after a session in which no pecks were made to S^{Δ}; those sessions are included in the figure.

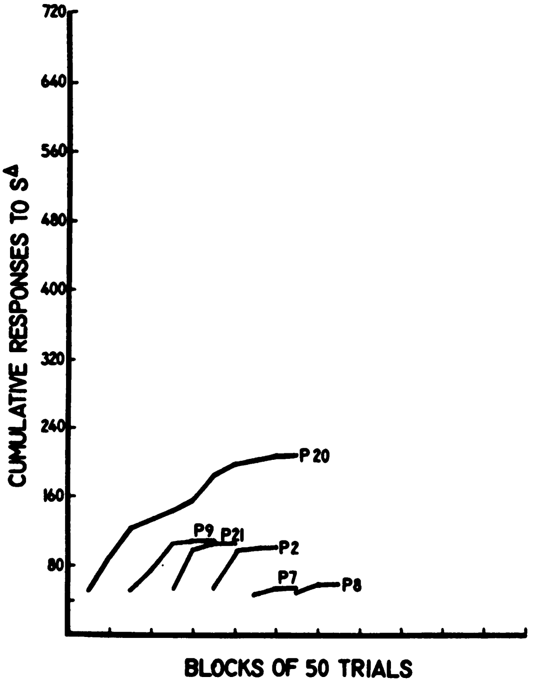

Fig. 4. Cumulative responses per session to S^{Δ}. Curves for the various birds are displaced along the abscissa; the scale is the same as that used in Fig. 2.

After responding on virtually all of the 50 S^{Δ} trials of the first session, birds with a hue discrimination ceased responding after one or two additional sessions; birds with the horizontal-vertical discrimination persisted somewhat longer, but did not show the sustained responding typical of the auto-maintenance performances shown in Fig. 2.

Since the persistent responding that characterizes auto-maintenance was not sustained by S^{Δ}, generalized pecking and reinforcement of pecking by stimulus change as such, seem inadequate to account for the auto-maintenance phenomenon. The main difference between S^{Δ} and a negatively correlated key is the pairing of the latter with grain on trials where pecks do not occur: this aspect of the procedure, then, appears to be responsible for the sustained pecking observed under the negative contingency.

The uniformly high tendency of all birds to peck S^{D}, even while S^{Δ} responses declined and disappeared, demonstrates that some visual information from the key was received on every trial. If "noticing the key", followed by an automatic "look-peck coupling" were sufficient to sustain continued responding, pecking of S^{Δ} would have persisted, just as pecking to the response key did in Exp. I. It is clear that noticing a stimulus that is never followed by grain does not lead to pecking.

EXPERIMENT III

The previous experiments indicated that pairing a response key with grain sustains pecking at the key, even though the key peck prevents reinforcement. The phenomenon of auto-maintenance is both surprising and difficult to pursue because of the failure of the negative contingency to exert a strong suppressive effect. In this experiment, a procedure designed to abolish pecking on the negative key was explored. Two differently colored keys were simultaneously illuminated and darkened on every trial. The negative contingency was in force on one key, but the other key was functionally irrelevant: pecks there had no scheduled consequence or greater significance than, for example, pecks on the floor or houselight. The development of responding on the functionally irrelevant key in preference to the negative key would indicate behavioral sensitivity to some aspect of the negative contingency, and would thereby provide a means of identifying more clearly the circumstances that sustain pecking on the negative key.

METHOD

Subjects

Two experimentally naive birds, and four others shifted directly from Exp. I, were maintained at 80% of their pre-experimental weights.

Procedure

The negatively contingent procedure of Exp. I was carried out exactly as described there except that a second key was illuminated and darkened along with the negative key. The two keys were distinguished by color—red or green—and the color correlated with the negative contingency was counterbalanced across birds. The center and right key positions were used, and position of the two key colors reversed in an unpredictable manner during all sessions, so that key color and not position was correlated with the contingency.

Results

Results of two birds trained from the beginning of the experiment with both negatively correlated and irrelevant keys are shown in Fig. 5. P-23 began pecking on the third day of training, and emitted substantial numbers of pecks on both the irrelevant and the negatively contingent key. The frequency of pecking the negative key declined during the next several sessions, and the significance of the key colors was reversed after a session in which the negatively contingent key was never pecked. On the day following reversal, no pecks were made on the irrelevant key (which had previously been negatively contingent) and the other key (previously irrelevant) was pecked on virtually every trial. During the next few days, however, this pattern reversed and by the end of the sessions shown, all pecking was again directed at the irrelevant key. Similar results were obtained for P-24; whenever the significance of the key color was reversed, pecking changed from the negatively contingent to the irrelevant key during the course of several sessions.

This bird showed a marked preference for the key that was initially irrelevant, so the first shift was made after two sessions during which the irrelevant key sustained substantial pecking and no pecks were made on the negatively contingent key. It is evident that the contingency exerted stronger control than the marked bias for pecking a particular key color, and that the locus of pecking shifted from the negatively contingent to the irrelevant key after all reversals of conditions.

The irrelevant key was similarly effective in birds that had previously been trained only on the negative key. Figure 6 shows the development of control by the irrelevant key in two birds that served as subjects in Exp. I. In both cases the irrelevant key gradually gained

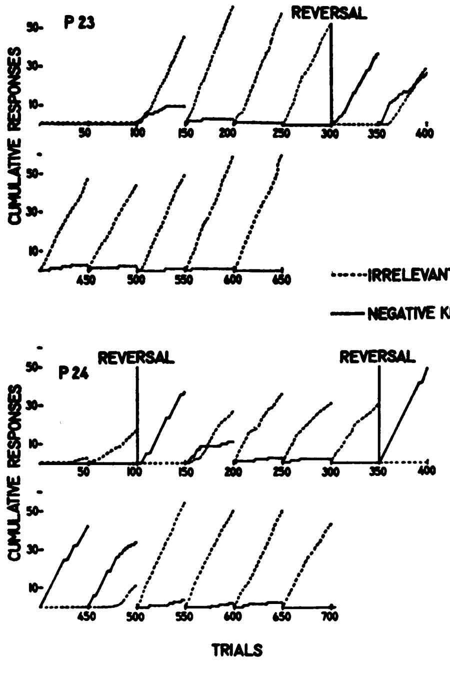

Fig. 5. Cumulative responses per trial to the negative and (on a reduced scale as indicated) the irrelevant key. The heavy vertical lines indicate when the significance of the key colors was reversed.

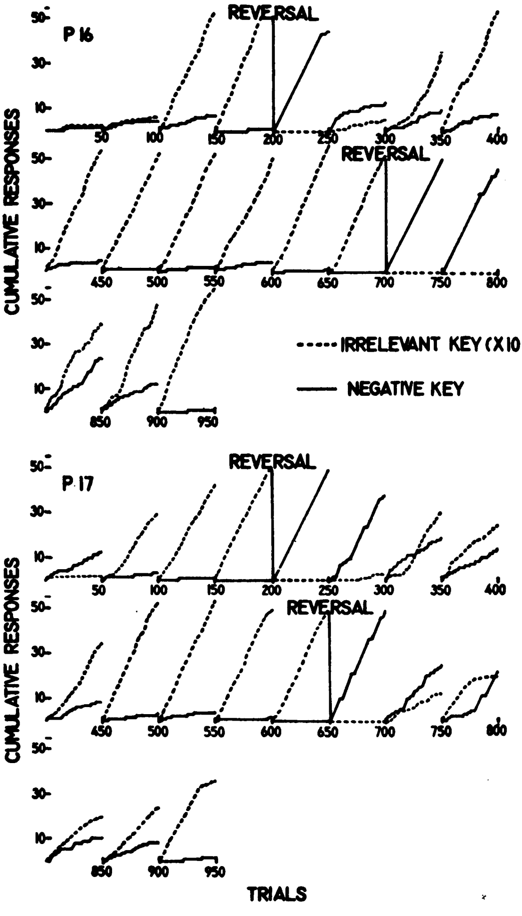

Fig. 6. Development of responding to the irrelevant key by two birds with a prior history of contingent non-reinforcement. The heavy vertical lines indicate where the significance of the key colors was reversed.

control during a series of sessions and, as with the naive birds, ultimately extinguished responding on the negatively contingent key. These results are typical of those of all four birds in which this procedure was carried out: in every case responding on the negatively contingent key ceased, and after reversal of stimuli, behavior shifted from the negatively contingent to the irrelevant key.

The continuing importance of the irrelevant key is suggested by the vigorous but gratuitous responding directed to it. It appears that the irrelevant key directs responding away from the negatively contingent key but does not produce an overall suppression. Direct evidence on this point was obtained by alternatively providing and omitting the irrelevant key in five-trial blocks. The negative contingency was effective only when the irrelevant key was present. When it was absent, the negative key was frequently pecked, though such responses prevented reinforcement. Apparently the irrelevant key provided a stronger stimulus for pecking than did the negative key. Even though it did not make the negative contingency effective by itself, the irrelevant key effectively demonstrated behavioral sensitivity to some aspect of the negative contingency.

EXPERIMENT IV

The only difference between the negative and irrelevant keys was the contingency scheduled on one and omitted on the other; as stimuli, both bore identical relationships to the grain reinforcer. The final experiment was carried out to determine whether intrinsic stimulus properties of the irrelevant key (as contrasted with those of other ostensibly suitable stimuli for pecking, such as the houselight) were responsible for its effectiveness, or whether the temporal relationship between the irrelevant key and the reinforcer was critical. In this experiment, a continuously illuminated but irrelevant key was substituted for the intermittent irrelevant key of Exp. III. As in the previous experiment, two keys were available on every trial, one scheduled with the negative contingency, the other with no contingency at all. The irrelevant key was also present between trials; it was darkened only during feeder presentations, and its location among the three key positions was changed at the start of each trial. If the mere availability of an irrelevant key is sufficient to support control by the negative contingency, a continuous key should substitute effectively for an intermittent one. However, if temporal relations between the irrelevant key and the reinforcer are important, the continuous key would not be an effective substitute. To assess the relative effectiveness of the continuous and intermittent irrelevant keys, additional birds received both continuous and intermittent irrelevant keys, while other birds were exposed only to the continuous key.

METHOD

Subjects

Four experimentally naive birds, and four others shifted directly from Exp. I, were maintained at 80% of their pre-experimental weight.

Procedure

The negatively contingent procedure of Exp. I was carried out exactly as described there with the addition of one or two other keys, distinguished by color from each other and from the negative key. For P-1916, P-2164, P-1909, and P-2096, a second key with no scheduled consequences was continuously illuminated except during feeder presentations. The position of this second key and the position of the negatively contingent key shifted at the start of each trial (defined by the presentation of the negatively contingent key). Both keys were distinctively colored and colors were counterbalanced for the four subjects. All three possible key locations were used, with two of the three being illuminated on any trial until a peck occurred or the reinforcer was presented. The negative key was darkened when pecked, but the continuous key did not go out. For P-1543, P-1728, P-1446, and P-1649, the procedure was exactly the same except that an intermittent irrelevant key was also present, and operated as in Exp. III. The intermittent irrelevant key had a third distinctive color, which was the same for all four birds, but the colors of the continuous and negative keys were counterbalanced. The location of all three key colors was shifted at the start of every trial, and following a peck or a reinforcement, the continuous key stayed in the same place until the onset of the next trial.

RESULTS

The two left panels (A and B) of Fig. 7 show responding over the course of the entire experiment for two birds trained first with the negative contingency alone; the right panels (C and D) show performance of two birds trained with a continuous key present from the start of the experiment. The two birds with only a continuous irrelevant key responded on the negative key for more than 30 sessions, and pecked far less on the continuous irrelevant key (Panels A and C). As in Exp. III, pecking on the negative key was controlled by the parallel presentation of an intermittent irrelevant key. Data from the other birds were entirely consistent with the results shown here: an irrelevant key presented along with the negative key enabled the contingency to gain control, but an irrelevant key that was continuously available did not.

The continuous key did not go entirely unpecked; P-1649, in fact, pecked more frequently on the continuous than on the intermittent key for the first four days after it was introduced. The timing of the pecks on the continuous key is of interest: not once during the experiment did a peck occur on the continuous key while the negatively correlated key was illuminated. Pecking was directed to the continuous key solely during the intertrial interval when it was the only key available.

Following the experiment proper, six birds were given additional training with the continuous key alone. The procedure was exactly as before except that the negative and intermittent irrelevant keys were never turned on. Because the location of the continuous key shifted when the trial began, it continued to signal the forthcoming presentation of grain; now, however, it was the only event to do so. Data from these sessions are shown to the right of the solid bars in Fig. 7. In all, four of the six birds trained under this procedure developed substantial pecking on the continuous key. Although pecking occurred throughout

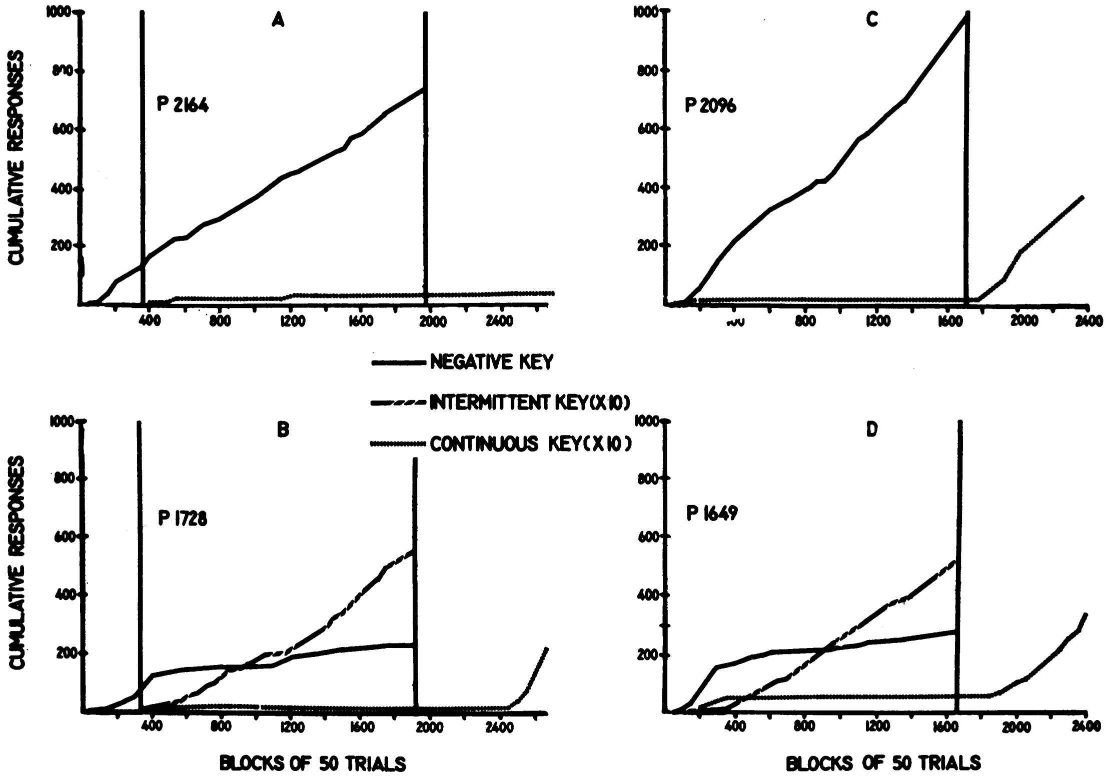

Fig. 7. Cumulative responses per trial to negative, intermittent, and continuous irrelevant keys. Panels A and B show cases where birds were trained first on the negative key only. Panels B and D show cases where three keys were present during the main part of the experiment. The heavy vertical lines within panels indicate changes in the variety of keys presented on each trial.

the session, it was concentrated in the 6 sec following a shift in the location of the key, when the presentation of grain was imminent.

The continuous key was not functionally similar to the intermittent key: it did not compete successfully with the negative key, nor was it pecked as often as the intermittent irrelevant key. The ineffectiveness of the continuous key is clearly consistent with the failure of other stimulus alternatives, such as the houselight, to substitute in function for the intermittent irrelevant key. If any of the effects reported in Exp. I and III were related to special characteristics of illuminated keys, the findings of those experiments would presumably have been disturbed by the presence of a continuously available key of similar appearance. The inability of the continuous key to compete with the negative key is particularly significant in light of the fact that responding finally developed, even in birds for which no key peck had ever been reinforced, when the continuous key was ineffective because it was a weaker stimulus for pecking, not because it was a wholly inadequate one. It could not have been weaker than the negative key because of extinction of pecking during the intertrial interval: due to the negative contingency, responses on the continuous key were inevitably more closely related to reinforcement than those on the negative key. On the other hand, the relative effectiveness of the negative key, compared to the continuous key, would seem also to be due to its association with the reinforcer: pairing of the negative key and the reinforcer established a relatively strong and directed tendency to peck on the negative key. Finally, the success of the intermittent irrelevant key in competing with the negative key would appear to depend in part on the fact that it bore the same stimulus-reinforcer relationship as the negative key, and to some consequence of the fact that reinforcement was never withheld in its presence.

GENERAL DISCUSSION

Successful auto-maintenance—persistent, directed key pecking despite contingent nonreward—does not seem to be a natural implication of either operant or respondent principles. Because actual pecking of the negative key produces nonreinforcement, it cannot be directly maintained by adventitious relationships. If it is supposed that unobserved behaviors preceding the actual striking of the key are adventitiously maintained, then either (a) one must assume that these adventitiously maintained precursors are inflexibly linked to pecking and account for why they are not extinguished or replaced by precursors for other responses, or (b) one must suppose that the precursors do not invariably lead to pecking but can precede other behaviors as well. If the latter assumption is made, then it is difficult to see why, by operant principles, the precursors do not become closely linked to some other behavior because of the consistent reinforcement such linkage would produce. Even if attention—heightened and directed by adventitious reinforcement and giving rise to behavior through a look-peck coupling—is assumed to be responsible for the initial pecks (Brown and Jenkins), it is difficult to see why the continual extinction of a specific response component would not lead to an operant shift in attention and inconsequential responding (when the negative key comes on, look at the continuous key and peck it). It is, for example, very difficult to see how the continuous key could ultimately control pecking but not compete with the negative key. It seems clear that stimulus-reinforcer relationships, and not only response-reinforcer interactions, play a special role in this phenomenon. Such a conclusion, of course, takes the phenomenon out of reach of a standard operant analysis, where the influence of stimuli depends on their discriminative function with regard to experimental contingencies.

Similarities to the respondent domain are easy to recognize: indeed, the auto-maintenance procedure is formally identical to the "omission training" procedure of Sheffield (1965) except that a key peck substitutes for a saliva drop. In the present case, the response at issue is topographically similar to the response made to food. However, even if one ignores the usual application of respondent analyses to autonomic rather than skeletal behavior, the directed quality of the induced pecking does not follow naturally from respondent principles (see also Brown and Jenkins, 1968). It is unclear, for example, why pecking would be directed at the key rather than the feeder, or indeed why it would be directed anywhere at all. Although respondent laws (which deal with laws of stimulus-reinforcer pairings) are no doubt pertinent to the present phenomenon, a detailed account of this phenomenon would seem to demand a serious augmentation of respondent principles to account for the directed quality of the response.

The most direct empirical precedent for the present phenomena is provided by the work of Breland and Breland (1961), who found, in several species, that response patterns that were related to a reinforcer could "drift" into a situation even though they delayed and interfered with actual production of the reinforcer. As in the present case, such behaviors were intrusive, counterproductive, and uncontrolled by their contingencies. In addition, it has been shown that pigeons trained to peck at other pigeons develop far more elaborate patterns of "aggressive" behavior than the actual contingency demands; the behavior is sometimes so vigorous that it continues into the period when reinforcement is available (Skinner, 1959; Reynolds, Catania, and Skinner, 1963; Azrin and Hutchinson, 1967). Similar effects have been reported in rats (Ulrich, Johnston, Richardson, and Wolff, 1963). When rats' running is reinforced, the speed at which they run is governed directly by the magnitude of the reinforcer, and fast running develops whether or not it produces more rapid reinforcement (Williams, 1966). These examples make it clear that contingencies of reinforcement alone do not determine when or how strongly some behaviors occur, even if the behaviors appear to be skeletal or "voluntary". As an instance of such direct control, the present phenomenon does not appear to be an isolated curiosity.

The place of this phenomenon in the general operant framework deserves explicit consideration. While it has always been recognized that many aspects of experiments, such as deprivation or physical details of the experimental space, influence the "operant level" of some responses, it now appears that many other variables, such as stimulus-reinforcer relationships, can also have an important influence on the unreinforced level of occurrence of some responses. That the stimulus-reinforcer pairing overrode opposing effects of differential reinforcement indicates that the effect was a powerful one, and demonstrates that a high level of responding does not imply the operation of explicit or even adventitious reinforcement. This point should be taken into careful account when effects of reinforcing contingencies *per se* are under investigation (see, for example, Herrnstein, 1966).

To relate the present work to the concept of "operant level" furnishes a context but does not provide an account. In further work, the concept of "arbitrariness", which is so frequently claimed for operants, will require close attention: is the action of reinforcement—direct or contingent—different when a response is "naturally" in the organism's repertory, or when it bears a special relationship to the reinforcer? More broadly, consideration should be given to ascertaining how frequently direct, as opposed to contingent, influences of reinforcers enter into the determination of "skeletal" or "voluntary" behavior in natural environments.

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