

*EFFECTS OF ALTERNATIVE REINFORCEMENT:
DOES THE SOURCE MATTER?*¹

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In a chamber with a single response key, pigeon's key pecks were reinforced with food according to a variable-interval schedule. In addition, extra reinforcements occurred concurrently according to an independent schedule. In one condition, availability of the extra reinforcements was signalled by a change in key color from white to red. The extra reinforcements occurred after a peck on the red key. In a second condition, the extra reinforcements were unsignalled and occurred only after a 2-sec pause in pecking for one group of subjects and were unsignalled and occurred freely as scheduled for another group of subjects. In the first two conditions, duration of reinforcement was varied. A third condition duplicated the second but varied rate rather than duration of reinforcement. The rate of pecking varied inversely with the amount of extra reinforcement per unit time according to the same function, regardless of the condition regulating occurrence of the extra reinforcements, and regardless of whether or not a 2-sec pause was required for their occurrence. The shape of this function was predicted by Herrnstein's (1970) matching law.

Studies of multiple and concurrent schedules of reinforcement of key pecking with pigeons have revealed an inverse relationship between rate of pecking and rate or amount of reinforcement from other sources. Reynolds (1961) found that rate of pecking during one component of a multiple schedule increased when reinforcement during the other component was discontinued, and decreased when reinforcement during the other component was reinstated. Herrnstein (1961) and Catania (1963a) found that rate of pecking on one key varied inversely with rate of reinforcement scheduled concurrently for pecking on another key.

In general, if response-A produces reinforcement-A and response-B produces reinforcement-B, an increase in reinforcement-B decreases response-A and a decrease in reinforcement-B increases response-A. This inverse effect, a contrast effect (Pavlov, 1927; Skinner, 1938), is stronger for simultaneous (concurrent) than for successive (multiple) schedules.

A given increase or decrease in reinforcement-B causes more variation in response-A when reinforcement-A and reinforcement-B are simultaneous than when they are successive.

Catania (1969) found that while simultaneous contrast (as in concurrent scheduling) is greater than successive contrast (as in multiple scheduling), the qualitative properties of successive and simultaneous contrast are identical. Shimp and Wheatley (1971) and Todorov (1972) have shown that as the component duration of a multiple schedule is reduced, responding in the two components begins to show the strong inverse relation found with concurrent schedules.

The closer in time reinforcement-A and reinforcement-B are to each other, the greater the contrast effect. Concurrent schedules intermingle reinforcement-A and reinforcement-B, thereby producing maximum contrast; multiple schedules alternate periods of reinforcement-A with periods of reinforcement-B, producing less contrast. If reinforcement-A and reinforcement-B are separated further in time (e.g., in different daily sessions), still less contrast is observed (Bloomfield, 1967).

The contrast effect is primarily an effect of reinforcement-B on response-A, not of response-B on response-A. Reynolds (1961) kept reinforcement-B constant in a multiple sched-

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ule, but reduced response-B by scheduling reinforcement for *not* responding in component-B. Despite the reduction to zero of response-B, there was no variation in response-A.

Nevin (1968) also scheduled reinforcement-B for not responding, but varied its rate. He found response-A to vary inversely with reinforcement-B regardless of the presence or absence of response-B. Halliday and Boakes (1971) reduced response-B by scheduling reinforcement-B independent of responding in a multiple schedule. Again, response-A did not increase. Only when reinforcement-B as well as response-B was reduced did response-A increase in the Reynolds, the Nevin, and the Halliday-Boakes experiments.

Catania (1963*a*) varied the rate of reinforcement-B in concurrent schedules, but kept response-B at a very low rate by signalling the availability of reinforcement on key-B. With key-A continually lit, a standard variable-interval schedule produced reinforcement of pecking on key-A. Reinforcement of pecking key-B was similarly scheduled, but a stimulus indicated when reinforcement was immediately available for a peck on key-B. Thus, the pigeons pecked key-A continuously, but pecked key-B only when the signal light was lit. Rachlin and Baum (1969) varied the amount of reinforcement-B while keeping response-B low by the same signalling technique. In Rachlin and Baum's experiment, response-B was not only low in rate, but constant throughout the experiment. In both the Catania and the Rachlin and Baum experiments, response-A varied inversely with reinforcement-B. Furthermore, the function relating response-A to the amount of reinforcement-B per unit time was identical in the two experiments. These experiments lead to the conclusion that, with regard to response-A, response-B is largely irrelevant. Holding other conditions constant, the critical determinants of response-A are the schedule of reinforcement for that response itself, and the amount of reinforcement from other sources, whatever they may be. While the particular function relating responding on key-A to reinforcement, dependent or independent of that response, is a subject of debate (Catania, 1963*a*; Lander and Irwin, 1968; Herrnstein, 1970) the general directions of the effects are clear. Reinforcement tends to increase the responding upon which it is dependent and

decrease other responding. For any particular response, dependent reinforcement is excitatory and all other reinforcement is inhibitory.

The fact that reinforcement from another source is inversely related to responding, while reinforcement dependent on the response itself is directly related to responding, raises questions about the distinction between the two sources of reinforcement. In normal concurrent and multiple schedules there are clear stimuli to indicate the two sources. In concurrent schedules with pigeons, reinforcement-A and reinforcement-B usually come from the same hopper, but they come after pecking keys of different colors at different locations. Catania (1969) brought the correspondence between pecking a specific key and reinforcement closer by putting subsidiary keys in the hopper. Reinforcement of pecking key-A could occur only by further pecking at key-A' located inside the hopper. Similarly, reinforcement of pecking key-B could only occur by further pecking at key-B', also located inside the hopper. Baum and Rachlin (1969) used separate hoppers in reinforcing the response of standing on one side or another of the experimental chamber. In neither case did the separation of sources of reinforcement-A and B increase the degree of contrast above that normally found with concurrent schedules.

All of the procedures in the present experiment used a single key with an alternative source of reinforcement. Since the timing of the variable intervals governing reinforcement proceeded concurrently for the two sources, the present experiments were studies of concurrent reinforcement. They studied the rate of response-A as a function of the amount or rate of reinforcement-B. They differed in the number of cues distinguishing the source of reinforcement dependent on response-A from the source of reinforcement independent of response-A.

METHOD

Subjects

Eight male White Carneaux pigeons were maintained at 80% of free-feeding weights. Four birds (S-30, -31, -32, and -33) had no previous experimental history, other than auto-shaping (Brown and Jenkins, 1968). The other four (S-1, -2, -484, and -486) had participated in a variety of earlier experiments.

Apparatus

The experimental chamber was a modified standard apparatus, 10.75 in. wide, 12 in. long, and 12.25 in. high (27.5 by 30.5 by 31 cm), designed for pigeons. A single response key, mounted 3.5 in. (9 cm) from the right-hand wall and 9.5 in. (23.5 cm) from the floor, operable by pecks of force greater than 0.14N, could be transilluminated with white or red light. The reinforcer was access to a standard grain magazine, the opening of which was in the center of the panel 3.5 in. (8.5 cm) from the floor.

Procedure

There were three basic conditions, within which amount or rate of reinforcement was varied. For all conditions, reinforcement was scheduled concurrently from two sources. One source (reinforcement-A) scheduled reinforcement of pecking the key, normally illuminated with white light. Except for control procedures, reinforcement-A occurred according to a 3-min variable-interval schedule (VI 3-min), and the duration of each exposure to grain was 4 sec. The other concurrent source (reinforcement-B) scheduled reinforcement of a single peck at the key when it turned red (Condition I), conditional upon the absence of pecking for 2 sec (Conditions IIa and IIIa), or freely without regard to pecking (Conditions IIb and IIIb). During Conditions IIa and IIb, amount of reinforcement (duration of each exposure to the food hopper) was varied. During Conditions IIIa and IIIb, frequency of reinforcement (value of the variable-interval schedule) was varied.

The contingencies for each condition were as follows:

Condition I. Two identical VI 3-min schedules operated for reinforcement-A and reinforcement-B. The key was transilluminated with white light continuously except when reinforcement-B was made available. Then the key changed from white to red and remained red until the pigeon pecked the key. A peck on the key when it was red produced reinforcement-B and darkened the key for the duration of the reinforcement. Pecks on the key while it was white produced reinforcement-A (and darkened the key) on the VI 3-min schedule. Thus, white illumination of the key signalled that reinforcement was not available from

source B, and red illumination of the key signalled that reinforcement was available from source B. Reinforcement availability from source A was not signalled. This procedure was identical to the signalled concurrent reinforcement technique of Catania (1963a) and Rachlin and Baum (1969), except that the signal appeared on the normally unsignalled key instead of on a different key, and no procedure in this condition corresponded to a change-over-delay. This procedure, therefore, removed one cue distinguishing reinforcement source B: the location of the key peck. The duration of grain presentation produced by pecking the key when it was white (reinforcement-A) and the duration of reinforcement produced by pecking the key while it was red (reinforcement-B) were varied as shown in Table 1.

Condition IIa. As above, two VI 3-min schedules ran concurrently. This time, however, the key remained white throughout the experiment. One schedule controlled reinforcement-A for pecking the white key as before. Reinforcement-B was scheduled as before but occurred only if the pigeon had *not* pecked the key for 2 sec. When reinforcement-B was scheduled, it would occur automatically, provided the pigeon had not pecked the key within the previous 2 sec. If there had been a peck within 2 sec, reinforcement was withheld until 2 sec passed without a peck. Then, the reinforcement occurred. After a peck-produced reinforcement (reinforcement-A), 2 sec had to pass without a peck before reinforcement-B could occur. Thus, of the cues distinguishing the two sources of reinforcement in the usual two-key concurrent schedule, only separation in time remained in this condition. The procedure added one cue, however: reinforcement-B never immediately followed a key peck. As before, duration of reinforcement was varied.

Condition IIb. This condition was the same as IIa except reinforcement-B occurred freely without the requirement of a 2-sec pause. In this condition, reinforcement-B sometimes occurred close in time to reinforcement-A and sometimes close in time to a key peck.

Condition IIIa. This was the same as Condition IIa, except that rate, rather than duration, of reinforcement was varied.

Condition IIIb. This was the same as Condition IIb except that rate, rather than duration of reinforcement was varied.

Table 1

Sequence of conditions of concurrent reinforcement-A and reinforcement-B for each subject. Within each condition, baseline, variation, and control procedures were conducted for 28 sessions, 1 hr each. After each variation, and each control procedure, there was a return to baseline for 28 sessions. Reinforcement-A was always scheduled for pecking a continuously lit white key. (VI—variable-interval; EXT—extinction.)

| Condition | Subjects | Reinforcement-A | | Reinforcement-B | | Contingency |
|--------------|-------------|-----------------|-----------|-----------------|-----------|---------------------------|
| | | Schedule | Amt (sec) | Schedule | Amt (sec) | |
| I | 30,31,32,33 | | | | | Peck on red key |
| baseline | | VI 3-min | 4 | VI 3-min | 4 | |
| variation | | VI 3 | 4 | VI 3 | 1 | |
| variation | | VI 3 | 4 | VI 3 | 16 | |
| control | | VI 3 | 16 | VI 3 | 4 | |
| IIa | 32,33,2 | | | | | No peck for 2 sec Free |
| IIb | 30,31,1 | | | | | |
| baseline | | VI 3 | 4 | VI 3 | 4 | |
| variation | | VI 3 | 4 | VI 3 | 1 | |
| variation | | VI 3 | 4 | VI 3 | 16 | |
| control | | VI 3 | 16 | VI 3 | 4 | |
| IIIa | 33,1,486 | | | | | No peck for 2 sec Free |
| IIIb | 30,2,484 | | | | | |
| baseline | | VI 3 | 4 | VI 3 | 4 | |
| variation | | VI 3 | 4 | VI 12 | 4 | |
| *variation | | VI 3 | 4 | VI 45-sec | 4 | |
| *control | | VI 45-sec | 4 | VI 3 | 4 | |
| **control | | EXT | — | VI 1.5 | 4 | |
| variation | | VI 3 | 4 | EXT | — | |
| ***variation | | VI 3 | 4 | VI 10-sec | 4 | |

*Sessions ended after 45 min rather than 1 hr.

**Run until extinction was complete rather than 28 sessions.

***Sessions ended after 9.5 min rather than 1 hr. Run until performance stabilized rather than 28 sessions.

Table I gives the parameters of the experiment. Each subject was exposed to the experimental conditions in the order of Table I (reading downward for conditions listed for that subject). For instance, S-30 was first exposed to Condition I, then to Condition IIb, then to Condition IIIb; S-1 was first exposed to Condition IIb, then to Condition IIIa; S-486 was exposed to Condition IIIa only.

Reinforcement-A and reinforcement-B were scheduled concurrently by two VI tape timers (Ralph Gerbrands Co.). The VI tapes used were: VI 3-min (18 intervals, shortest 5 sec), VI 12-min (10 intervals, shortest 37 sec), VI 45-sec (14 intervals, shortest 5 sec), and VI 10-sec (14 intervals, shortest 1.25 sec). All were derived from the distribution suggested by Fleshler and Hoffman (1962). When a VI tape assigned a reinforcement, the tape timer was stopped until the end of the feeder presentation. When one of the VI tapes stopped, the other tape was unaffected, until reinforcement

occurred. During reinforcement, both tapes stopped.

At the start of each condition, pigeons were exposed to a baseline procedure (providing equal reinforcement from sources A and B) for 28 sessions. Then, rate or amount of reinforcement-B was changed to another value for 28 sessions, and then the baseline procedure was reinstated for 28 sessions. After each variation (and each control procedure), the pigeons were returned to baseline. Table I describes the initial baseline procedure but, for the sake of brevity, the returns to baseline after each variation are omitted from the table.

With three exceptions, all baseline, variation, and control procedures were presented for 28 sessions for each pigeon. Initially, Condition I was given for 14 sessions at each duration of reinforcement-B, but stability of rate of pecking was not reached within 14 sessions, so Condition I was rerun (with the same pigeons) for 28 sessions at each duration. The

results are reported for the latter cycle only. The second exception to the 28-session rule was a control procedure of Condition III, in which reinforcement-A was changed to Extinction. This procedure, which was maintained for 50 sessions unless a pigeon made no pecks on three of five consecutive days before 50 sessions, lasted an average of 33 sessions for Condition IIIa and 50 sessions for Condition IIIb. The third exception was the last variation procedure run in Condition III (VI 3-min for key pecking, and VI 10-sec response-independent reinforcement). This procedure was continued until performance appeared stable (53 sessions), because two of the birds failed to stabilize within 28 sessions.

All sessions ended after 1 hr, except the VI 45-sec variation and control procedures of Condition III, which lasted 45 min, and the VI 10-sec variation of Condition III, which lasted 9.5 min. These sessions were shortened to prevent the pigeons from becoming satiated by the high rates of reinforcement.

In the procedures labelled "baseline" and "variation" in Table 1, reinforcement-A was kept at VI 3-min with 4-sec reinforcement while reinforcement-B was varied. In the procedures labelled "control" in Table 1, reinforcement-A was varied while reinforcement-B was kept at VI 3-min with 4-sec reinforcement. The control procedures were tests for non-instrumental effects of reinforcement, such as reduction of responding due to satiation. For instance, if 16-sec durations of reinforcement-B reduced responding only because the prolonged reinforcements satiated the pigeons, then responding should be similarly reduced with 16-sec durations of reinforcement-A. If, on the other hand, 16-sec durations of reinforcement-B reduced responding because they were independent of the response, then responding should not be reduced with 16-sec durations of reinforcement-A.

The first four procedures listed under Condition III parallel those of I and II. Further procedures in Condition III were presented at extremely high and low rates of reinforcement so that responding could be examined over a wide range of reinforcement values.

RESULTS

Figure 1 shows, for each pigeon, for each condition, the function relating rate of re-

sponse to per cent total reinforcement obtained by pecking. Abscissa values were obtained by the following formula:

$$\text{Relative total reinforcement obtained by pecking} = \frac{r_A a_A}{r_A a_A + r_B a_B} \quad (1)$$

where r_A, r_B = nominal rate of reinforcement-A and -B (reinforcements per hour)

a_A, a_B = nominal amount (duration) of reinforcement-A and -B (sec)

Nominal, rather than actual values, were used

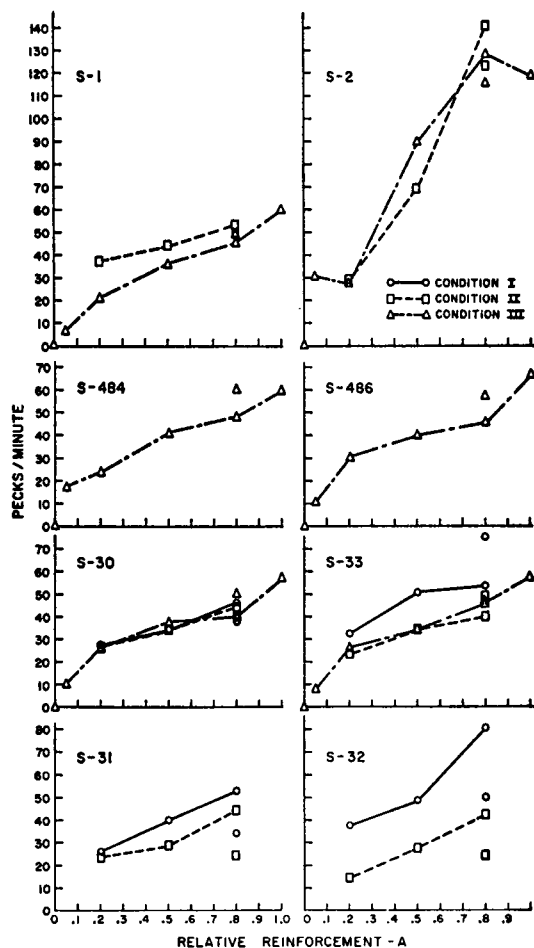


Fig. 1. Rate of response for each pigeon, for each procedure, as a function of relative total reinforcement-A. Each point is the median rate of the last 11 sessions at that point, except at the abscissa value of 0.5 (baseline), which is the average of three or six 11-day medians. The connected points represent constant reinforcement-A and varying reinforcement-B. The unconnected points are control points where reinforcement-A was varied. See Table 1 for description of different conditions.

because (a) the actual rates of reinforcement were within 10% of the nominal rates in all conditions, (b) the actual amounts are unknown because only hopper-time-up was measured, not time spent eating, and (c) several ordinate values with slightly different actual rates but with identical nominal rates were averaged. Since, for each procedure, either $r_A = r_B$ or $a_A = a_B$, the per cent total reinforcement is either relative amount or relative rate of reinforcement. The formula allows the two independent variables to be compared.

The ordinate values for each pigeon are the median rates of response of the last 11 sessions in each procedure. There was one such median for each variation and control procedure within each condition. Since baseline determination preceded each variation and control procedure, there were three baseline medians in Conditions I and II, and six baseline medians in Condition III. Within each condition, the arithmetic mean of the three (or six) baseline medians is plotted in Figure 1 on the same curve as the single median for each variation. The control medians are shown as separate points.

Assuming that all the curves in Figure 1 pass through the origin, their general shape can be described as a monotonic, increasing, concave downward function. The general similarity of the curves for all conditions cannot be attributed to insensitivity to the experimental manipulations. On the contrary, the fact that every variation in reinforcement-B (no matter how confounded with reinforcement-A) produced substantial inverse variation in response-A indicates that the pigeons of this experiment were extremely sensitive to the dependency of reinforcement on response. Pigeons exposed to the most confounding situations first (e.g., S-1 and S-484) were as sensitive as those exposed previously to signalled reinforcement-B. The control procedures show that (with the possible exception of S-31 and S-32) satiation was not the cause of the reduced responding with high rates and amounts of reinforcement-B. When these same high rates and amounts were provided for reinforcement-A in the control procedures, responding increased above the baseline level, except for S-31 and S-32. The increases were generally as great as or greater than the increases in rate of response when

reinforcement-B was decreased. In other words, the unconnected points in Figure 1 generally fall near or above the lines.

In Condition III, one control procedure consisted of extinction of response-A with continuation of reinforcement-B. This procedure was the only one to reveal a difference between the free-reinforcement (undelayed) and the 2-sec-non-response (delayed) contingencies of reinforcement-B. From the points shown in the figures, which are medians of the last 11 sessions, it can be seen that all birds eventually came to respond at rates close to zero. The speed of extinction differed for the two conditions, however. The numbers of sessions needed for S-33, S-1, and S-486 (the 2-sec non-response pigeons) to drop to a response rate of less than 10% of that on the last day of the preceding baseline procedure were 7, 8, and 8, respectively. The corresponding numbers of sessions for S-30, S-2, and S-484 were 10, 11, and 18, respectively. Thus, although the imposition of the 2-sec delay between pecks and reinforcements had no effect upon ongoing response rate, it did accelerate extinction.

Both groups of pigeons in Condition III responded more in extinction than pigeons normally do after VI reinforcement. In this respect, the present experiment parallels investigations of "superstition" (Herrnstein, 1966) and confirms their results.

For summarizing the data across animals, medians were used, rather than means, because the frequency distributions of response rates tended to be highly asymmetrical. This was particularly true of those procedures involving S-2.

Comparisons of the effects of delayed and undelayed free reinforcement on the same subject can be made for S-1 and S-2 (see Table 1). In Figure 1, the two curves for each of these birds suggest no striking differences in the effects of the two procedures. Figure 2, which summarizes the data across the groups, shows that, despite the difference in speed of extinction, the two types of response-independent reinforcement had similar effects on the concurrent response. The abscissa is the same as in Figure 1. The response rates (ordinate values) have been corrected for differences in overall rate across groups. They are expressed as a proportion of the response rate when reinforcement-B was 4-sec long and occurred

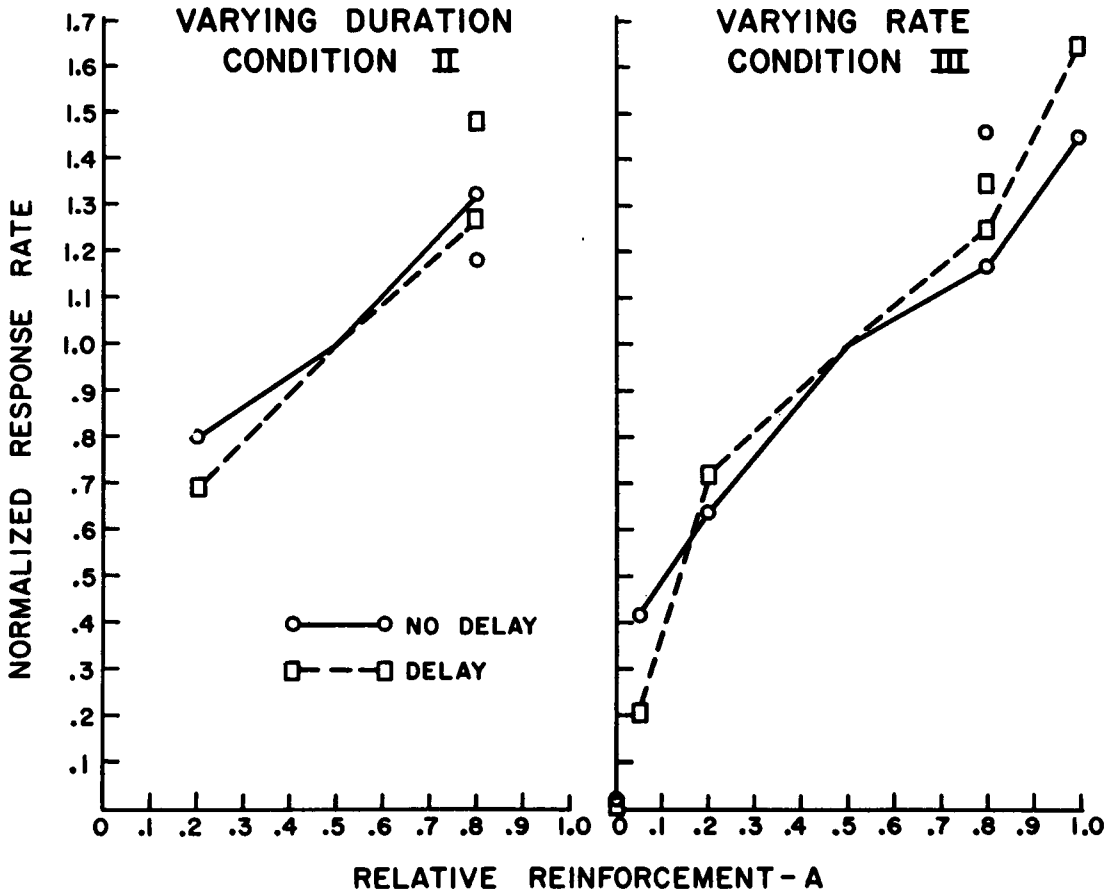


Fig. 2. The ordinate values of Figure 1 were normalized at the 0.5 abscissa point (baseline) and medians were taken across subjects exposed to Conditions IIa, IIb, IIIa, and IIIb.

on a VI 3-min schedule (relative reinforcement-A equal to 0.5). It can be seen in Figure 2 that there are no substantial or systematic differences between the two groups of pigeons, either for varying duration or varying rate of reinforcement.

Figure 3 summarizes the data for the three conditions of varying reinforcement-B. The abscissa and ordinate are as in Figure 2. Although the curve for Condition II appears to be slightly steeper than the others, it is unlikely that this difference can be attributed to any factor other than chance. The curves for Condition I, the other condition in which duration of reinforcement-B varied, and Condition II, the other condition in which reinforcement-B was response-independent, coincide almost perfectly. Thus, it appears from Figure 3 that all three conditions produced the same variation in performance.

In sum, the results show that regardless of how the alternative reinforcement occurred, and regardless of whether it varied in amount or rate, it produced the same effect on the concurrent VI performance.

DISCUSSION

This experiment showed that pigeons can discriminate between response-dependent and response-independent reinforcement on the basis of dependency alone.

Conditions IIb and IIIb, where response-independent reinforcement was simply superimposed on ongoing responding would seem to be ideal for adventitious reinforcement of pecking (*i.e.*, "superstition"). There must have been occasional instances of a response immediately preceding a response-independent reinforcement. These reinforcements could have in-

creased the rate of responding, just as they would have if they were response-dependent. If the only effect of r_B on responding was to provide occasional additional response-dependent reinforcements, however, the pigeons' rates of responding would have increased (Catania and Reynolds, 1968) and not decreased, as they actually did. The more response-independent reinforcement, the lower the rate of pecking—exactly the opposite of what one would expect if response-independent reinforcements were adventitiously reinforcing key pecking.

It could be argued that the response-independent reinforcement strengthened behaviors other than key pecking, at least some of which were incompatible with key pecking. Increasing the rate or amount of response-independent reinforcement might increase the frequency of these incompatible behaviors and decrease the frequency of key pecking. The lack of any difference in the effects of delayed and undelayed non-contingent reinforcement, however, seems to invalidate such an explana-

tion of the results. Whereas the undelayed reinforcements must often have coincided with key pecks, the delayed reinforcements never could. Yet, the delayed reinforcements produced no greater decrease in key pecking. It seems more likely that molar correlations between responding and reinforcement, or the lack thereof, controlled the discrimination of the two sources of reinforcement. The pigeons must have been sensitive to these correlations irrespective of whether, in particular instances, a given reinforcer followed a given response.

In a recent review of the effect of adventitious reinforcement on responding, Staddon and Simmelhag (1971) came to the same conclusion. They say,

... adventitious reinforcement implies failure of constancy, in the sense that the animal is presumed to be unable . . . to distinguish between real and accidental correlations between his behavior and the occurrence of reinforcement. This is a strong assumption, in view of the adaptive utility of the constancy process and its ubiquity in perceptual and motor mechanisms. In perception, a similar failure to distinguish changes in sensory input that are produced by our own behavior from changes that are independent of behavior might cause us to perceive the world as rotating every time we turn our head. It is of course true that on the basis of one or a few instances the animal may not be in a position to be certain about the reality of a contingent relationship between his behavior and reinforcement—and this kind of sampling limitation might account for a transient superstitious effect. It is less convincing as an account of a long-term effect. (P. 21)

This view calls into question the notion of superstition itself. If it were true, various experimental procedures, such as the change-over delay, designed to circumvent adventitious reinforcement of changeovers in concurrent schedules, would have to be reevaluated. Recent studies have questioned the role of the changeover delay in relation to adventitious reinforcement (Shimp and Wheatley, 1971; Todorov, 1971, 1972.) They have viewed concurrent schedules as a form of multiple schedule, where the organism controls the

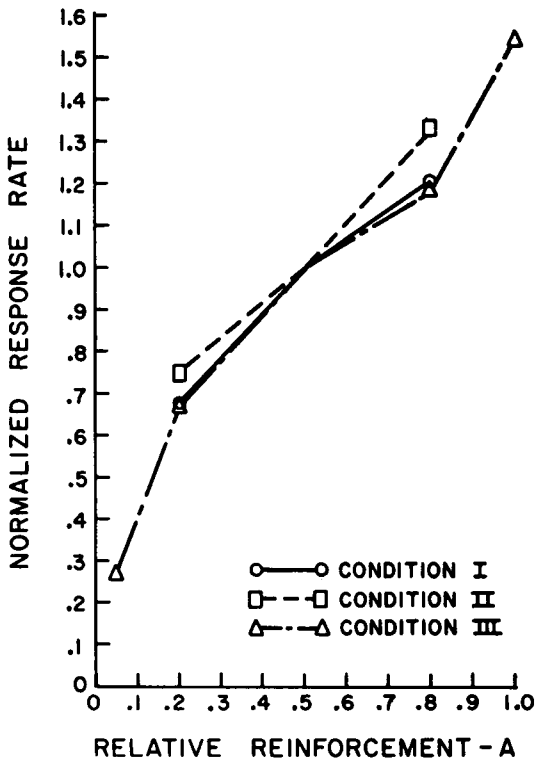


Fig. 3. The ordinate values of Figure 1 were normalized at the 0.5 abscissa point (baseline) and medians were taken across subjects exposed to Conditions I, II, and III.

component duration by switching from key to key. The changeover delay penalizes such switching of components. According to Todorov (1971), low changeover rates accentuate measured preferences for one key or another because of local rate changes immediately after a changeover. The present experiments (Conditions IIa and IIIa) also made use of a form of changeover delay, between responding and not-responding. Here, local rate changes might not be expected to appear. In any case, the changeover delay had no effect on responding, although it did accelerate extinction.

Herrnstein (1970) proposed a general quantitative formulation to account for variations in responding with reinforcement for that behavior and reinforcement from alternative sources. Applied to the present experiment, his formula produces the equation:

$$P_A = k \frac{v_A}{v_A + mv_B + v_0} \quad (2)$$

where P_A is the rate of key pecking for reinforcement-A, v_A and v_B are the reinforcing values of sources A and B ($a_A r_A$ and $a_B r_B$ in Equation 1), m , which might be called the "coefficient of interaction", varies between 0 and 1, and v_0 is a constant that represents the reinforcing value of all the other, unscheduled, sources of reinforcement in the situation. In Herrnstein's original equations, v_A , v_B , and v_0 could be expressed as r_A , r_B , and r_0 because amount was held constant. Here, v is held to represent the product of rate (r) and amount (a), as in Equation 1.

In the usual two-key concurrent situation, m in Equation 1 equals 1.0. That is, the following equation describes responding at either alternative:

$$P_A = k \frac{v_A}{v_A + v_B + v_0} \quad (3)$$

This equation has been verified with rate of reinforcement varying (Herrnstein, 1970) and with duration (amount) of reinforcement varying (Catania, 1963b). It seems reasonable, therefore, to expect that Equation 3 would fit the present data.

Figure 4 shows that the fit is quite good. The open circles are median response rates, across all subjects in all the conditions of the present experiment. The solid curve represents Equation 3, with $k = 210$ and $v_0 = 240$.

It is noteworthy that the value of v_0 required to fit the data is higher than usual. Herrnstein (1970) reported values of his parameter R_0 that were generally less than 10. In the present context, this would correspond to a v_0 of 40, substantially lower than the value of 240 used in Figure 4. Herrnstein (1970, Figures 8 and 9) reported one instance of R_0 equal to 180 ($v_0 = 720$), and one instance of R_0 equal to 300 ($v_0 = 1200$). The v_0 of 240, therefore, while large, is not so large as to prevent application of Equation 3 to the present data.

Herrnstein's (1961, Figure 2) data from typical two-key concurrent VI VI schedules showed response rate on either key to be approximately proportional to the relative rate of reinforcement for that key. This would suggest a small, even negligible, value of v_0 in Equation 3. The broken curve in Figure 4 illustrates the effect of making v_0 smaller and more in keeping with Herrnstein's (1961, 1970) findings. Although the smaller v_0 permits a good fit to the righthand points in Figure 4, the lefthand points (reinforcement-B substantially larger than reinforcement-A) lie far above the curve. The size of v_0 necessary to fit data from such concurrent experiments, therefore, depends greatly on the range of variation of reinforcement-B. This relationship makes comparison with other existing data difficult, because the range of variation of reinforcement-B has generally been relatively narrow. The filled circles and crosses in Figure 4 represent data from Catania (1963a) and Rachlin and Baum (1969). Since they approximately parallel the solid curve, it is easy to see that they fit Equation 3, except with a smaller value of k than that given in Figure 4 for the data of this experiment. The data points for Rachlin and Baum (1969) come from a procedure in which reinforcement-B was signalled and produced by pecks at a second key. The data points for Catania (1963a) come from a similar procedure and from typical concurrent VI VI schedules; the data from the two procedures were similar.

Should it prove that the more usual concurrent procedures reliably produce smaller values of v_0 than atypical procedures like those of the present experiment, one would conclude that somehow these procedures make pigeons unusually "distractable". That is, the procedures somehow enhance the value (v_0) of sources of reinforcement (grooming, exercise,

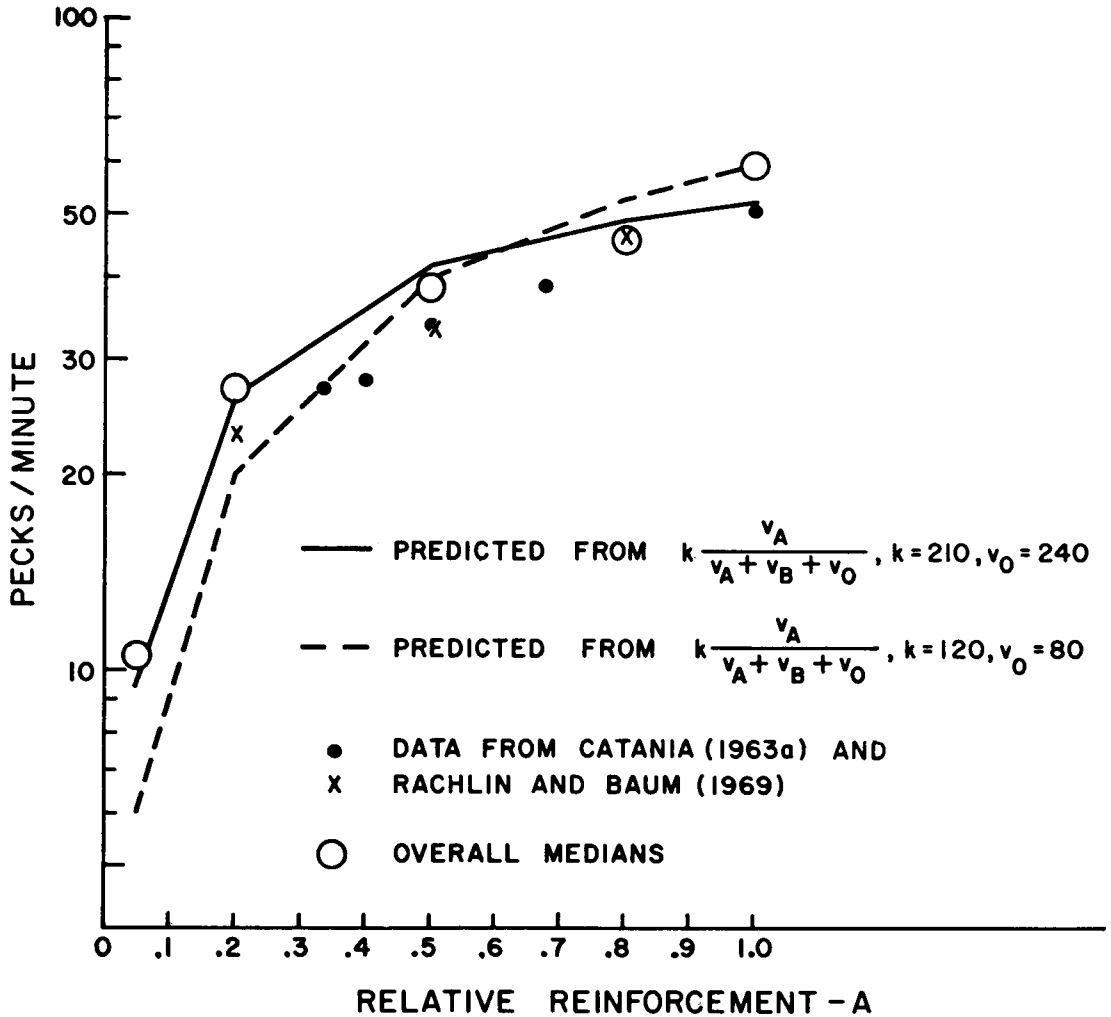


Fig. 4. Medians of the ordinate values of Figure 1 across all subjects and all conditions (open circles) and means across subjects in the Catania (1963a) and Rachlin and Baum (1969) experiments (filled circles and crosses). The solid line represents the matching equation (Equation 3) with $k = 210$, $v_0 = 240$. The dotted line represents the matching equation with $k = 120$, $v_0 = 80$.

exploration, *etc.*), other than reinforcement-A and -B.

One way in which the present procedures differ from normal concurrent procedures is that for a given reinforcement rate, the overall response rate in the present experiments was lower than the sum of the response rates on the two keys in the normal concurrent procedure. The enhanced v_0 might result from the decrease in overall rate.

There are two further questions that can be raised with respect to Figure 4. The first has to do with the leftmost point. Without this point, the remainder of the function could be fitted reasonably well by a straight line

intersecting the abscissa at a non-zero value. Is the point artificially low? The evidence indicates that it is not. In Figure 1, the triangles at the zero abscissa value show that when relative reinforcement-A is made zero, by extinction of response-A, pecking eventually ceases; in other words, the origin is also a point on the curve. A further check was made with the pigeons used in Condition III. The pigeons were exposed to the standard VI 3-min schedule for pecking and, in addition, given freely available food (a cup of grain). This was an attempt to minimize relative reinforcement-A (the abscissa) by increasing reinforcement-B, rather than decreasing reinforcement-A. All

six pigeons were run under identical conditions here. One (S-484) of the six pigeons stopped pecking within 10 sessions. The remaining five (three of which had been exposed to the delay procedure previously) pecked at a low rate ranging from 0.2 to 15 pecks per minute (11-day medians) at the end of 40 sessions. The median rate of the five pigeons that pecked was six pecks per minute. This adds to the evidence that the function of Figure 4 curves downward at abscissa values close to zero and, incidently, confirms the finding of Neuringer (1969) that pigeons will respond in the presence of free food. In fact, Neuringer's finding, instead of appearing as an anomaly, becomes a point on the function of Figure 4 represented by a high, but not infinitely high, rate of free reinforcement.

A second question about Figure 4 regards the validity of fitting an equation (Equation 3) with two arbitrary parameters to the averaged data of Figure 4. It is quite probable that other equations with other parameters would provide as good a fit. The advantage of the matching equation is that it reconciles the present results with those obtained with concurrent schedules, with concurrent-chain schedules, with multiple schedules, with standard single-manipulandum variable-interval schedules, and with apparent anomalies such as found by Neuringer. The present results add to the accumulating evidence that differences between the parameters k , v_0 , and m of Equation 2 can account for behavior under a wide variety of conditions that would otherwise seem to differ along irreconcilable qualitative lines.

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