BEHAVIORAL CONTRAST

GEORGE S. REYNOLDS[1]

HARVARD UNIVERSITY

A pigeon's rate of key pecking during the presentation of one stimulus may be altered by changing only the schedule of reinforcement associated with a *different* stimulus (Reynolds, 1960). A change in behavior during the presentation of one stimulus, brought about by changing the schedule associated with a different stimulus, is called an *interaction*. The change in behavior is called a *contrast* when the change in the rate of responding during the presentation of one stimulus is in a direction *away from* the rate of responding generated during the presentation of the other stimulus. For example, the schedule of reinforcement associated with a red key is held constant while appropriate operations increase or decrease the rate of responding during the presentation of a green key. If the rate of responding with a red key decreases when the rate with a green key increases (or increases when the other decreases), the change in rate during the presentation of red is called a contrast.

Contrast typically occurs during the formation of a discrimination between two stimuli. Responding is reinforced first in the presence of each of two exteroceptive stimuli and subsequently in the presence of only one (S^D). As the rate of responding during the presentation of the other stimulus (S^{Δ}) decreases, the rate of responding during S^D increases over the rate maintained when responding was reinforced in the presence of each stimulus. Smith and Hoy (1954) and Herrick, Myers, and Korotkin (1959) have reported examples of contrast in an operant discrimination. Verplanck (1942) and Solomon (1943) have reported a similar effect in running speed and jump-stand latency. In Hanson's (1959) generalization gradients, the "post-discrimination shift" in the wavelength controlling the maximum rate of responding is accompanied by an increase in the rate of responding during S^D.

The discrimination need not be formed between an S^D and an S^{Δ}. Contrast seems to occur even when the extinction schedule is replaced by a schedule which merely programs fewer reinforcements than the schedule in force during S^D. Findley (1958) showed that the rate of responding on a VI 6-minute schedule of reinforcement in one component of a multiple schedule increased when the schedule in the other component was a VI with a mean interval greater than 6 minutes (cf., also Schuster, 1960). Similarly, when Herrnstein and Morse (1957) superimposed a stimulus correlated with "response-independent" reinforcement upon a DRL base line, the rate of responding in the presence of the superimposed stimulus greatly exceeded the rate normally maintained by "response-independent" reinforcement alone.

The development of performance on a fixed-interval schedule of reinforcement is a process similar to contrast. Early in the development, a constant rate of responding typically prevails throughout the interval. As the rate of responding in the early part of the interval, where responding is never reinforced, decreases below this constant level, the rate of responding in the last of the interval, where responding is always reinforced, increases above the constant level (cf., Ferster & Skinner, 1957, p. 136). The increase in rate in the last of the interval is in a direction away from the decrease in the early part of the interval.

Pavlov (1927) has reported a contrast in salivary conditioning. He called the effect

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[1] I wish to thank Dr. R. J. Herrnstein for criticism of the research and of the manuscript. The present data comprise Experiment I in a dissertation submitted to the Department of Psychology, Harvard University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

"induction" (but cf., Skinner, 1938). Pavlov wrote, "The secretory effect was increased almost 50 per cent when the positive conditioned stimulus was applied immediately [up to two minutes in some cases] after the termination of the inhibitory stimulus [S^{Δ}], and the latent period of the reflex was definitely shortened. Moreover, *the intensity of the motor alimentary reaction of the animal was also considerably increased.*"[2]

The preceding examples of contrast in instrumental and salivary conditioning occur as the result of the manipulation of the schedule of positive reinforcement[3] in the presence of only one of two stimuli. In each example, the change in schedule in the presence of one stimulus that results in contrast in the presence of a different stimulus generates both a reduction in the frequency of reinforcement and a decline in the rate of responding. Extinction, for example, generates a lower rate of responding and a lower frequency of reinforcement than the VI schedule with which it produced contrast in the experiment of Herrick, Myers, and Korotkin (1959). The confounding of these two variables means that the contribution of each alone to the production of contrast cannot be assessed. In the present experiments, the contribution of these two variables is separated by generating a low rate of responding at the same time as a high frequency of reinforcement.

METHOD

Apparatus

The experimental chamber was a modified picnic icebox similar to that described by Ferster and Skinner (1957). A standard response key, 0.75 inch in diameter, was mounted on one wall of the chamber. The minimum effective force for operating the key was about 20 grams. The key could be transilluminated by red, green, orange, or blue lamps fixed behind it. Beneath the key was a 2-inch-square opening through which the pigeon was occasionally given access to grain for 3 seconds. The chamber was illuminated by two 6-watt white lamps. White noise masked most extraneous sounds.

Subjects

Four adult, male White Carneaux pigeons, numbered 32, 33, 34, and 35, were used in each procedure. They had been trained previously to peck at a response key for food reinforcement on a variety of schedules of reinforcement. Pigeons 34 and 35 were used only in Procedures I and II. Each bird was maintained at 80 per cent of its free-feeding body weight unless otherwise specified.

Procedures

In each of the four procedures, a daily experimental session consisted of 30 cycles of a two-component multiple schedule. Each cycle consisted of 3 minutes of red- or orange-key illumination (first component) followed by 3 minutes of green- or blue-key illumination (second component). The schedule of reinforcement for pecking in the first component (i.e., associated with the first stimulus) was always a variable-interval (VI) schedule with a mean interval of 3 minutes. Several different schedules were used in the second component.

Procedure I. Four pigeons were reinforced on the multiple schedules summarized in

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[2] Lecture XI, italics mine.

[3] Contrast may also occur with procedures using aversive stimulation in only one of two components of a multiple schedule. The "compensatory increase" in responding after a conditioned aversive stimulus (Estes & Skinner, 1941) may be interpreted as a contrast. Azrin (1956, p. 17) has reported increases in the rate of responding in one component of a multiple schedule when responding is punished in the other component.

Table 1. During the time out (second component of Phase 2), there was no illumination behind the key or in the chamber and no reinforcements were delivered, although operations of the key were recorded.

Procedure II. A schedule of "reinforcement for not responding" was the second component in one phase of Procedure II. In this schedule, the food magazine operates whenever the pigeon has not pecked the key for a specified time *t*. The time without responses is measured from the start of the stimulus with which the schedule is correlated or from the last response in the presence of that stimulus. Each response begins a new interval of not responding. The interval is terminated by presenting a reinforcer after *t* seconds of no responding. Such a schedule involves *differential reinforcement* of behavior *other* than key pecking. It may be called DRO *t*, where *t* is the interval of no responding necessary for reinforcement. In these experiments, the value of *t* was between 50 and 75 seconds. Since each component is 180 seconds long, the first integer less than $180/t$ gives the maximum possible number of reinforcements per exposure to the schedule.

Pigeons 34, 35, 32, and 33 were reinforced on the multiple schedules summarized in Table 2. The two groups of birds differ in the order in which the schedules were programmed. In Phase 4 for Group II, Pigeon 33 had DRO 75 seconds (instead of DRO 50 seconds) only for Session 4; Pigeon 32 had DRO 75 seconds for Sessions 4–7.

Procedure III. This is a combination of Procedures I and II. After reinforcement on a multiple schedule in which both components were VI, the second component was changed to a combination of time out and DRO. There was no illumination behind the keys or in the chamber, and a reinforcer was presented every *t* seconds, provided that no response occurred.

The sequence of multiple schedules is summarized in Table 3. Pigeon 32 was not used in the second session in Phase 3 because it weighed 20 grams more than usual at the beginning of the session.

Table 1

Procedure I

Phase	Multiple Schedule	Pigeon	Number of Sessions
1	VI VI	34	4
		35	3
		32	6
		33	4
2	VI TO*	34	5
		35	5
		32	6
		33	6
3a	VI VI	32	10
		33	8
3b	VI EXT	34	6
		35	6

*TO: time out

Table 2

Procedure II

Phase	Multiple Schedule	Pigeon	Number of Sessions
Group I:			
1	VI VI	34	4
		35	5
2	VI DRO 50 sec	34	10
		35	11
3	VI VI	34	5
		35	6
4	VI EXT	34	8
		35	11
5	VI VI	34	5
		35	5
Group II:			
1	VI VI	32	6
		33	6
2	VI EXT	32	6
		33	6
3	VI VI	32	5
		33	5
4	VI DRO 50 sec	32	7
		33	9
5a	VI EXT	33	7
5b	VI VI	32	7
		33	5

An additional procedure controlled for the effects of increasing the frequency of reinforcement by changing the second component from VI 3 minutes to DRO. After the last session of Procedure III, the usual body weight of each bird was increased by increasing its daily ration of grain. Pigeon 32 increased from 422 to 452 grams; Pigeon 33, from 404 to 420 grams. On the next day, the procedure was the same as that of Procedure II, except that no reinforcements were delivered during the time out in the second component.

RESULTS

Behavioral contrast is an increase in the rate of responding in one component of a multiple schedule when certain changes occur in the other component. In this experiment, the first component is always VI and the schedule in the second component varies. The question is simply this: What variations in the second component increase the rate of responding in the first component, and what variations leave it constant?

The results show that both time out and extinction produce increases in responding in an alternated, VI component. Reinforcement for not responding in addition to either time out or extinction, however, does not produce an increase. Moreover, the effect of reinforcement for not responding is not due to changes in the organism's body weight.

The data are shown in Fig. 1–6. Figures 5 and 6 contain selected cumulative records of responding as a function of time. Figures 1 and 3 show, for each bird, the number of responses per session in the VI component of the multiple schedule. The different curves in each graph arise from procedures in which the sequence of schedules in the *other* component was different. These sequences of schedules are given as the labels of the curves.

For example, a pigeon is exposed to the sequence of multiple schedules VI VI, VI EXT. Responding in the first component is plotted, where the schedule is VI in both multiple schedules. The curve is labeled VI-to-EXT since that is the sequence of schedules in the second component. If extinction in one component produces contrast in the other, the curve of responding for the VI component will rise.

I. Performance was stabilized on the multiple schedule VI VI. Subsequently, the second component was changed to a time out during which there was no chamber or key illumination, and no reinforcements were delivered. The first component was maintained as VI.

The responding in the component maintained as VI is shown as the VI-to-TO curve in Fig. 1 for Birds 34, 35, 32, and 33 in Parts A, B, C, and D, respectively. Session 0 represents the last session on the schedule, mult VI VI. During the subsequent sessions, the schedule was mult VI TO. If the change of schedule in the second component had no effect upon responding in the VI component, the VI-to-TO curve would be a straight, horizontal line. For each of the birds, however, the number of responses in the first component increases in the first session after the change from VI to time out in the second component. For all birds except 35 (Part B), the number of responses per session under mult VI TO remains higher than under mult VI VI. The number of responses generated by a VI schedule of reinforcement in one component of a multiple schedule increases when the schedule in the other component is changed from VI to time out.

For two birds, 34 and 35, the second component was changed from time out to extinction. This change consisted only of illuminating the chamber and key during the second component. Responding after this change is shown as the TO-to-EXT curve in Parts A and B of Fig. 1. For Pigeon 34 (Part A), the number of responses per session is relatively constant at the level to which it had increased on the previous multiple schedule, VI TO. The curve for Pigeon 35 (Part B) shows an initial increase in responding (Session 1, TO-to-EXT curve) and

Table 3

Procedure III

Phase	Multiple Schedule	Pigeon	Number of Sessions
1,	VI VI	32	10
		33	8
2	VI (TO + DRO 75 sec)	32	2
		33	2
3	VI (TO + DRO 55 sec)	32	2
		33	3

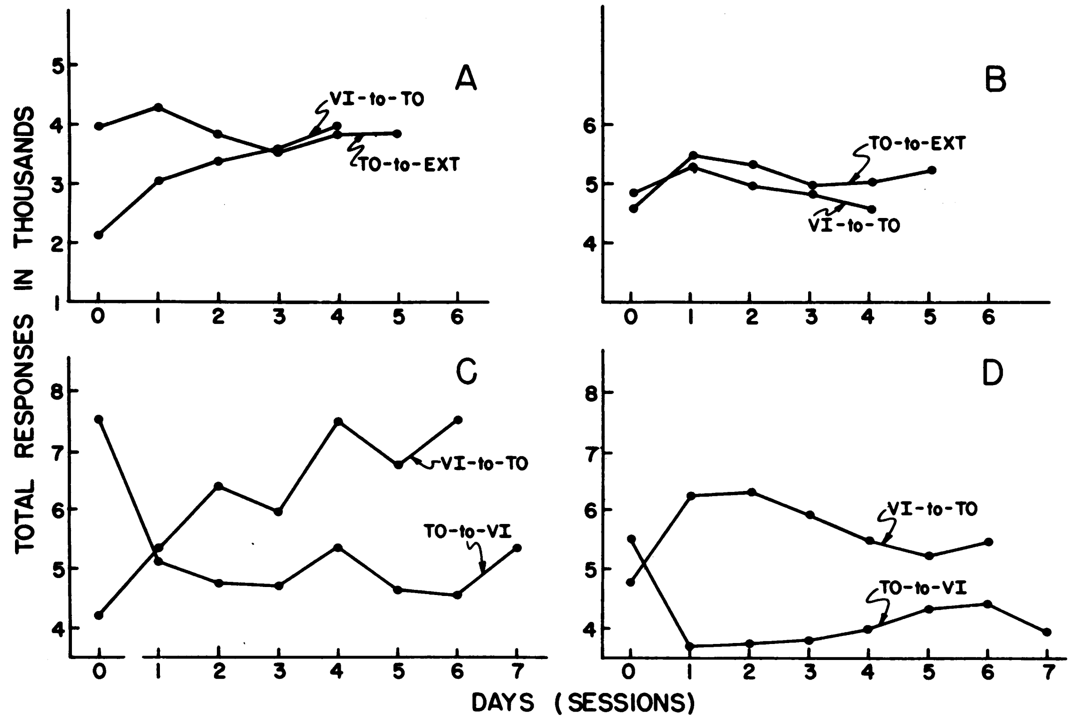

Figure 1. The total number of responses per session in the first component of a two-component multiple schedule. The schedule of reinforcement in the first component is always VI. The label of each curve gives the sequence of schedules in the second component of the multiple schedule. Each part of the figure shows reponding for a different pigeon.

then a steady performance at a level greater than that originally maintained by the schedule mult VI VI.

For Pigeons 32 and 33, the second component was changed from time out to VI. This change consisted of not only illuminating the chamber and key but also reinstating the VI 3-minute reinforcement schedule. Responding after this change is shown as the TO-to-VI curves in Parts C and D. For each bird, the number of responses per session decreases to approximately the level originally maintained by mult VI VI.

The responding from the component that was changed from VI to TO has not been shown, because the number of responses in time out never exceeded 20 per session.

Average curves for each procedure are shown in Fig. 2. Before averaging, each curve for each bird was normalized by dividing the number of responses in each session by the number of responses in Session 0. The normalized curves, all of which begin at 1.0, were averaged across birds.

The abrupt, nearly complete absence of responding in the first session under time out produces an increase in the rate of responding in the component that is maintained on VI (VI-to-TO curve, Fig. 2). When time out is changed to extinction, there is little change in responding (TO-to-EXT); but when time out is changed to VI in the second component, the rate of responding in the other, VI component, declines (TO-to-VI curve).

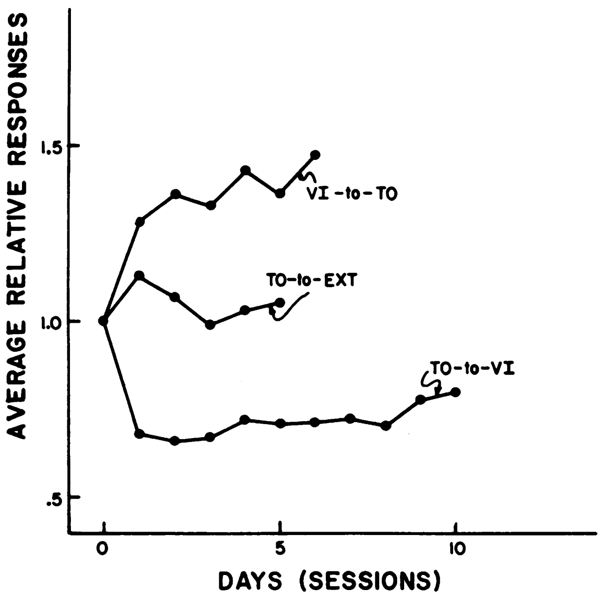

Figure 2. Average normalized curves for each sequence of schedules in Procedure I. Before averaging, each curve for each bird (Fig. 1) was normalized by dividing the number of responses in each session by the number of responses in Session 0. Each point in the VI-to-TO curve is the arithmetic mean of four observations. Each point in the other two curves is the arithmetic mean of two observations.

II. The first component of the multiple schedule, VI VI, was maintained as VI, while the other component was changed from VI to reinforcement for not responding (DRO 50 seconds), back to VI, then to extinction, and again to VI for Birds 34 and 35. The reverse sequence of schedules was used for Birds 32 and 33.

The number of responses per session in the component that was maintained as VI is shown in Fig. 3 Parts A, B, C, and D for Pigeons 34, 35, 32, and 33, respectively. The label of each curve is the sequence of schedules in the second component of the multiple schedule. The first schedule in the label refers to Session 0; the second, to the subsequent sessions. The first column of graphs shows curves for procedures in which the schedule in the second component was changed from VI to extinction (VI-to-EXT curve) or to DRO 50 seconds (VI-to-DRO curve). The histogram at the bottom of each graph in the first column shows the number of reinforcements per session in the DRO component. The second column of graphs shows curves from sessions in which the schedule in the second component was changed from extinction (EXT-to-VI curve) or DRO (DRO-to-VI curve) to VI. The number after each label refers to the chronological order in which the curve was obtained.

Generally, the number of responses per session in the VI component increases when the other component is changed from VI to extinction and does not increase when the other component is changed from VI to reinforcment for not responding for 50 seconds (DRO 50 seconds). The VI-to-EXT curves rise and remain higher than those at Session 0. The over-all rise in the VI-to-DRO curves is not so great. Inversely, responding in the VI component decreases when the schedule in the other component is changed from extinction to

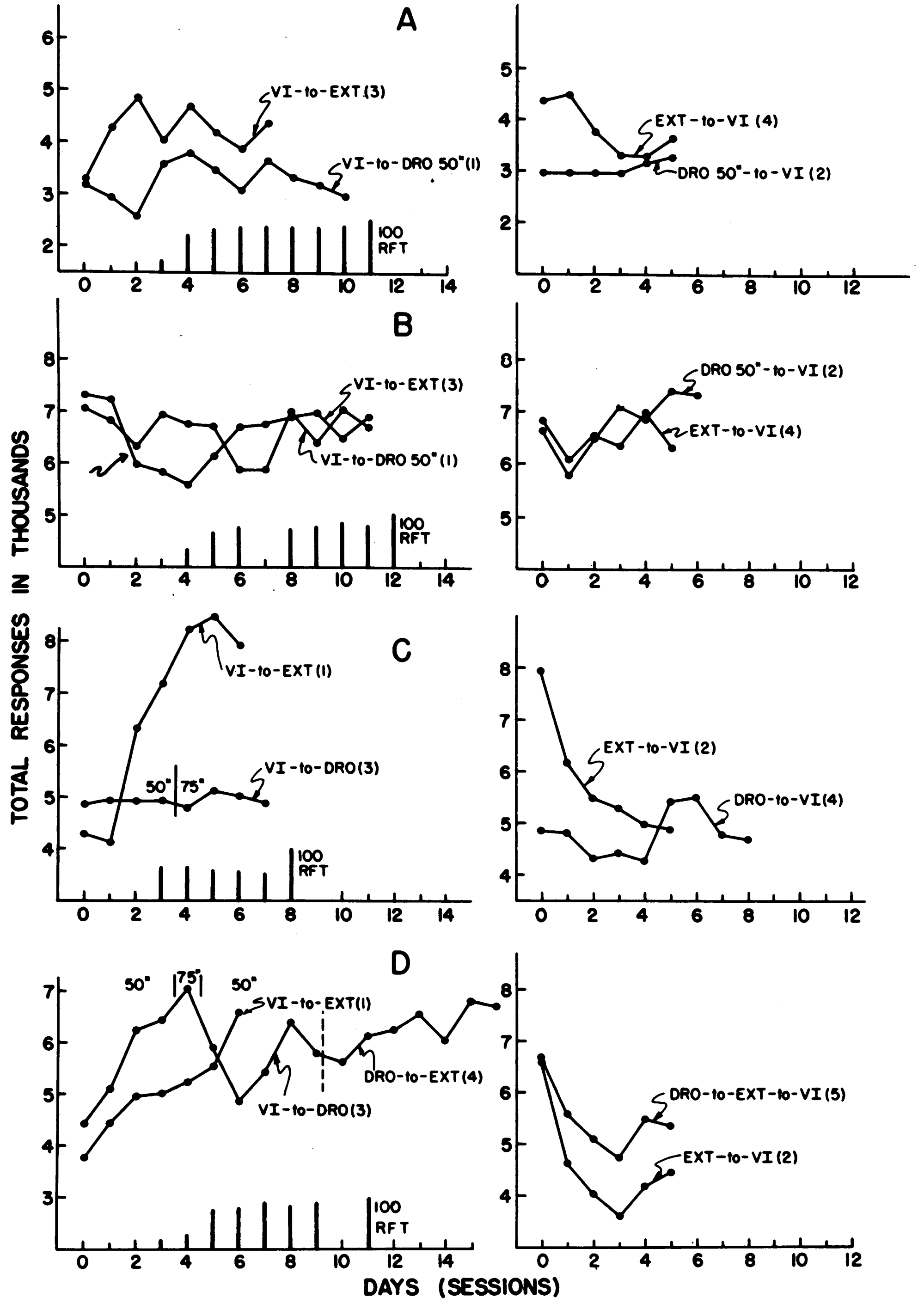

Figure 3. The total number of responses per session in the first component of a two-component multiple schedule. The histograms show the number of reinforcements per session in the component of the multiple schedule in which not responding was reinforced. Each row of graphs shows responding for a different pigeon.

VI and increases slightly when the change is from DRO to VI. The EXT-to-VI curves (second column) generally decrease, and the DRO-to-VI curves slightly increase.

Pigeons 34 and 32 (Parts A and C) show these general results clearly, especially 32, Part C. Pigeon 35 (Part B), however, fails to show an increase in responding in the first component when VI is changed to extinction in the second component (VI-to-EXT curve). In Session 2 of that procedure (arrow), in which a large drop in the number of responses occurs in the VI component, two successive exposures to VI contained no reinforcement. The rate of responding in the next two VI periods was nearly zero, and the rate was lower than usual throughout the remainder of the session. In Session 5, an increase in the number of responses per session begins, but its final level in Sessions 8–11 is not greater than the level maintained in the VI-to-DRO curve. This pigeon was exposed to the VI-to-EXT procedure after the VI-to-DRO procedure. The order may have biased the result. Despite the lack of net increase in the VI-to-EXT curve, the EXT-to-VI curve suggests a slight decrease in responding. The DRO-to-VI curve, on the other hand, shows an increase.

The VI-to-DRO curve for Pigeon 33 (Part D) illustrates the differential effects of extinction and DRO. This curve increases during the first four sessions in which the frequency of reinforcement on the DRO procedure is nearly as low as during extinction (histogram). When the frequency of reinforcement in the DRO component increases in Sessions 5 and 6, the number of responses in the VI component decreases. The final point on the VI-to-DRO curve shows a number of responses greater than the number at Session 0. Nevertheless, the number of responses in the first component increased when the DRO reinforcements were discontinued (Sessions 10–16).

The second column of Part D shows the number of responses in the first, VI, component when the schedule in the other component is changed to VI from extinction (EXT-to-VI curve), or from extinction after DRO (DRO-to-EXT-to-VI curve). Both curves decrease, but the EXT-to-VI curve decreases more. The number of responses in the last session on the DRO-to-EXT-to-VI curve (Session 5, column 2) is nearly equal to the number of responses in the last session on the VI-to-DRO curve (Session 9, column 1).

The data have been summarized in Fig. 4 by averaging the individual performances on each procedure. Before averaging, each curve was normalized by dividing the number of responses in each session by the number of responses in Session 0. Since each curve begins at 1.0, the differences in the performance on VI under different procedures in the other component can be readily seen. The VI-to-EXT curve increases and the EXT-to-VI curve decreases, while the DRO-to-VI and VI-to-DRO curves change relatively little.

Selected cumulative records of responding during the change from mult VI VI to mult VI DRO are shown in Fig. 5 for Birds 34, 35, and 33, respectively. Each group of records has been labeled with the number of the bird whose performance it illustrates. For example, the three records (A, B, and C) labeled 34 show the performance of Pigeon 34. The records for the two components of the multiple schedule have been distinguished by displacing and holding the recording pen downward throughout the second component. In the records, the curve of responding for the second component is continuous with, but 1 millimeter lower than, the curve of responding for the first component. In the records of Pigeons 34 and 35, the recording pen was reset to the base line after each cycle of two components.

The occurrence of reinforcements is indicated by short vertical lines, as at *a* in the group of records for Pigeon 34.

The first group of records from Pigeon 34 shows the responding during the last hour of the last session on the multiple schedule VI VI (Record A) and the responding at the end of

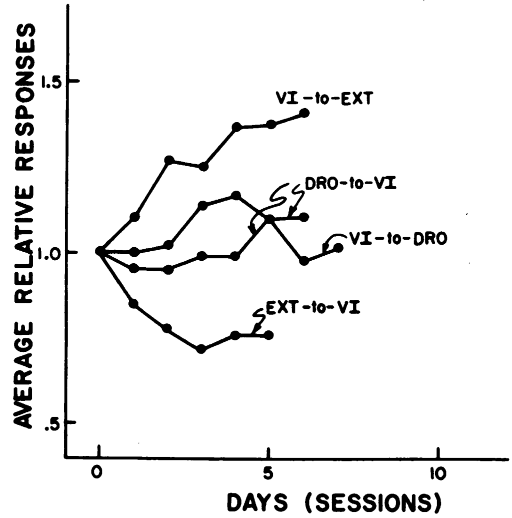

Figure 4. Average normalized curves for each sequence of schedules in Procedure II. Before averaging, each curve for each bird (Fig. 3) was normalized by dividing the number of responses in each session by the number of responses in Session 0. Each point is the arithmetic mean of four observations.

Sessions 2 and 3 on the multiple schedule VI DRO 50 seconds (Records B and C). The effect of reinforcement for not responding for 50 seconds (DRO reinforcements) is a low rate of responding (slope of the cumulative record) in subsequent VI components. The first DRO reinforcements are received at *a* and *b* in Record B, and the rate of responding is lower in the next VI component, at *c*. At the end of the next day (Record C), a DRO reinforcement is received at *d*, and slight pauses appear in the next VI component. High rates of responding and no reinforcements at *e* and *h* in the DRO component are followed by high rates in the next VI component, such as at *i*. Low rates of responding and DRO reinforcements at *f* and *j* are followed by VI components with long pauses at the beginning, at *g* and *k*. After several exposures to components with 2 and 3 DRO reinforcements (end of Record D), the rate in the VI component is steady but lower (at *l*) than at the start of Record D.

The second group of records shows similar behavior from Pigeon 35. Several DRO reinforcements, as at *a* in Record B (end of Session 4 on mult VI DRO), are followed by VI components with pauses at the beginning (at *b* and *c*) or soon after reinforcement (at *d*). A DRO component without reinforcement (at *e*) is followed by a VI component without a pause (at *f*). Record C (next day) shows rates of responding in the VI component that are generally lower than the rate prevailing in Record A under mult VI VI. At this stage in the development of control by the DRO schedule, high rates of responding occasionally occur (1) at the start of a DRO component (as at *g*, *h*, and *i*) and (2) after a DRO reinforcement (as at *j*).

The last group of records shows the responding of Pigeon 35. Record A shows the end of the last session on mult VI VI; and Record B, the end of the third session on mult VI DRO. The rate of responding at *a*, before DRO reinforcements are received, is higher than the rate in the first component in Record A. This increase in rate is reflected in the initial increase of the VI-to-DRO curve in Part D of Fig. 3. The first DRO reinforcements are received at *b*, *c*, and *d*, and three occur in one DRO period at *e*. The rate is lower in the next VI component at *f* and in subsequent VI components in Record B. Record C shows the first hour of the fifth session. DRO reinforcements are frequent, and the VI performance shows pauses (as at *h*), rates equal to those at *a* (as at *i*), and rates lower than

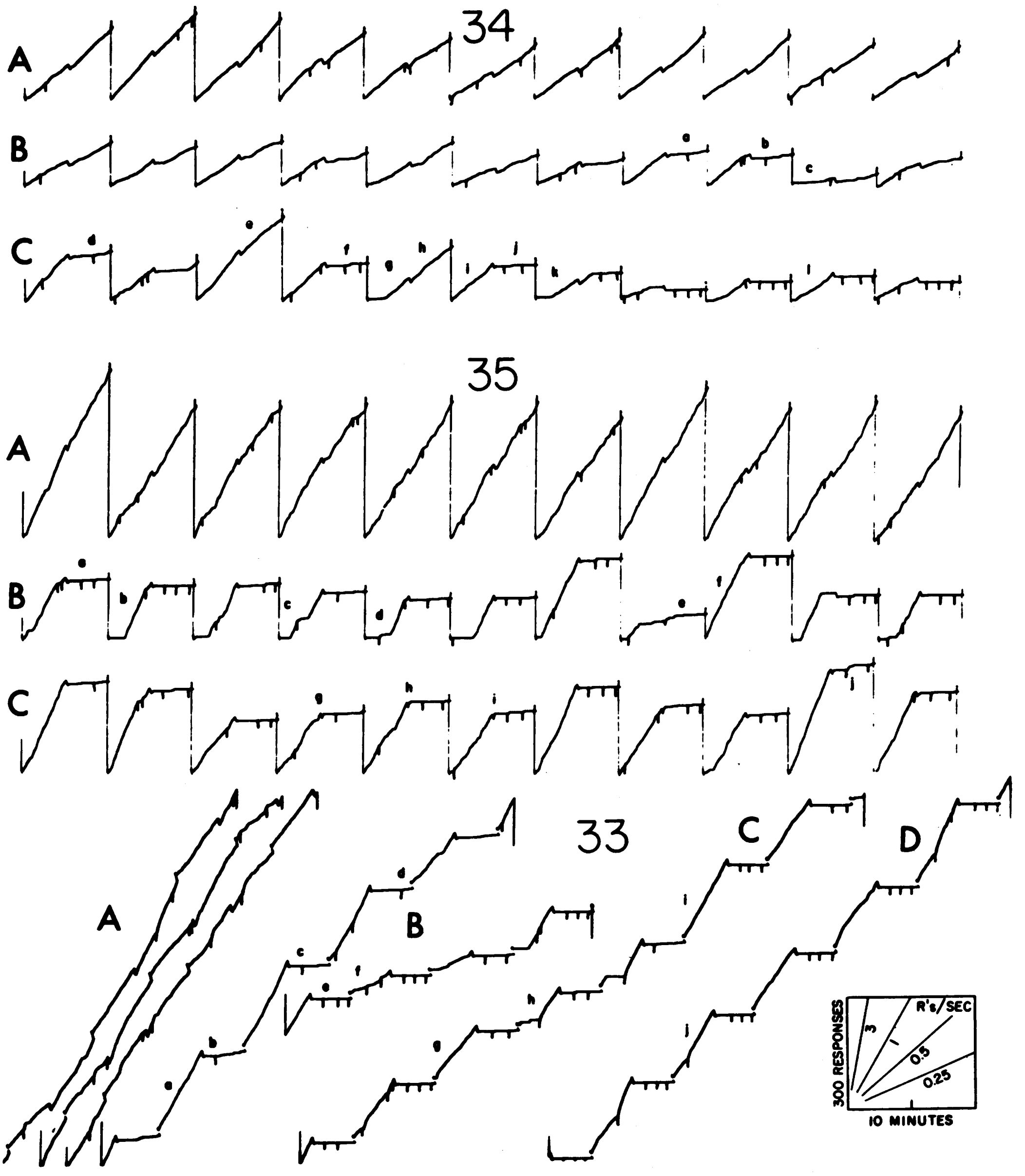

Figure 5. Cumulative records of the responding of three pigeons on a sequence of multiple schedules including reinforcement for not responding. The recording pen was displaced downward throughout the second component. The curve of responding for the second component is continuous with, but 1 millimeter below, the curve of responding for the first component. Reinforcements are indicated by short vertical lines on the records.

those at *a* (as at *g*). By the end of that session (Record D), the rate of responding in the VI component is lower than at *a* and slightly higher, on the average, than in Record A (under mult VI VI). Occasionally, very high rates of responding occur just after reinforcement in the VI component, as at *j*.

The rate of responding in a component whose schedule is maintained as VI reinforcement increases when the schedule in the other component is changed from VI to extinction. The increase does not occur if reinforcement for not responding (DRO) is received in the extinction component. The initial effect of DRO reinforcement is pausing in the VI component. After several hours, the pauses become less frequent and shorter. These results show that contrast may be reduced by programming reinforcement for not responding during extinction.

III. Pigeons 32 and 33 were reinforced on a series of multiple schedules in which the first component was maintained as VI reinforcement while the second component was changed to time out, back to VI, to time out plus reinforcement for not responding, and back to VI.

The initial change from VI to time out in the second component resulted in an increase in the number of responses per session in the component maintained as VI (cf., Fig. 1). When reinforcement for not responding (DRO) was programmed in addition to time out, a permanent increase in responding in the VI component did not occur.

After five sessions of time out plus DRO alternating with VI, both birds were fed an amount of grain sufficient to increase their weights: by 30 grams for Pigeon 32; by 16 grams for Pigeon 33. The next session consisted of the multiple schedule, VI TO; the DRO procedure was omitted.

The cumulative records from the first cycles of each session are shown in Fig. 6. Each part shows the responding under the multiple schedule, VI (TO + DRO) in Record A; and under VI TO in Record B. Part I is Bird 32; Part II, Bird 33. The recorder pen is displaced down throughout the second component.

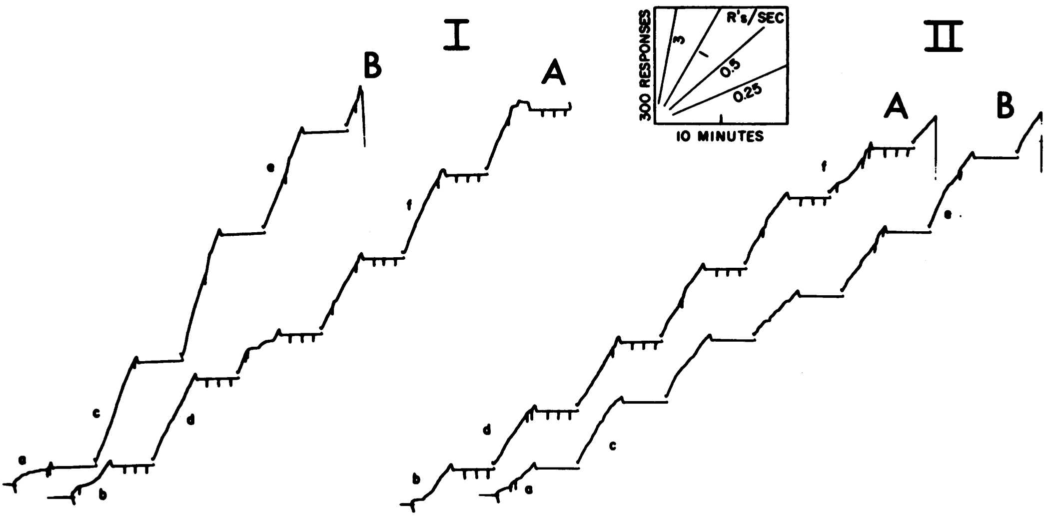

Figure 6. Cumulative records of responding for two pigeons. Each pigeon weighed more during Record B than during Record A. No reinforcements for not responding were received during Record B.

The rate of responding in the VI component is higher after time out (Record B) than after time out plus DRO reinforcement (Record A). For both birds, the rates at *c* and *e* in Record B are higher than at *d* and *f*. The differential effect is immediate (the *c* vs. *d* comparison) for both birds, and it occurs despite the increase in weight, which normally may be expected to decrease the rate of responding (Ferster & Skinner, 1957). The difference in rates between *c* and *d* may not be explained as day-to-day variation since the difference between the VI rates in the first VI component (*a* vs. *b*) is in the opposite direction.

DISCUSSION

A behavioral contrast is a change in the rate of responding during the presentation of one stimulus in a direction away from the rate of responding prevailing during the presentation of a different stimulus. Typically, the rate of responding on a variable-interval or variable-ratio schedule when the key is red (for example) increases when the schedule of reinforcement associated with a green key is changed from reinforcement to extinction (cf., Fig. 4). The first of the present experiments shows that a slow decline of responding is not necessary. Contrast occurs when extinction is replaced by a time out (no lights in the chamber and no reinforcements), which immediately produces a near-zero rate of responding. The production of contrast during the presentation of the red key is one of the functional properties of both extinction and time out.

Contrast during the presentation of one stimulus is eliminated by reinforcing not responding in the presence of the other stimulus. Given either a slow decline of responding in extinction (Procedure II) or an immediate decline in time out (Procedure III), the rate of responding on a VI schedule in the presence of a different stimulus does not increase when food is presented after intervals of no responding during extinction or time out. The absence of contrast on the VI schedule is inferred from either (1) no increase in the rate of responding (Procedures II and III), (2) a further increase in responding when reinforcement for not responding is withdrawn (Procedure III), or (3) a slight increase in responding when VI reinforcement is reintroduced during the presentation of the other stimulus (Procedure II).

The absence of contrast during the presentation of a red key when DRO reinforcements are delivered during the presentation of a green key might be interpreted in either of two ways. The rate of responding during red may not rise because of induced pausing from the performance on the DRO schedule. Reinforcing not responding increases the frequency of behaviors incompatible with pecking during green. These behaviors (pausing) tend also to occur during the VI performance. Their occurrence decreases the rate of pecking during the presentation of red.

On the other hand, if the absence of reinforcement, rather than a low rate of responding, creates a necessary condition for contrast, then DRO eliminates contrast by providing reinforcement.

Both processes may be involved. In the first session with DRO (Record C, Fig. 5), the pigeon typically pauses at the start of the performance on VI (as at *g* and *k*). The pauses might be interpreted as induction from the DRO performance. Later, however, the long pauses disappear, and the rate of responding is steady and not higher than in the control session (cf., at *l* in Record D, Fig. 5). Does the length of the induced pauses decrease or is a necessary condition for contrast removed by the DRO procedure?

The induction interpretation, in which pausing is a reinforced response, is unlikely in view of the immediate increase in the rate of responding on VI when DRO reinforcement is removed from the alternated schedule (end of Procedure III, Experiment I). Figure 6 shows that the increase occurs in the very next presentation of the stimulus correlated with the VI schedule. If induced pausing were lowering the rate on the VI schedule, more than one 3-minute exposure to time out without DRO would certainly be needed to extinguish the pausing tendencies. The immediacy of the contrast effect seems to preclude an interpretation in terms of variables than work gradually.

Contrast appears rather to depend upon a relation among the schedules of reinforcement currently controlling an organism's behavior. The results of the present experiments and of those summarized in the introduction suggest the following relativistic specification of the conditions for contrast. The frequency of reinforcement in the presence of a given stimulus, *relative to the frequency during all of the stimuli that successively control an organism's behavior,* in part determines the rate of responding that the given stimulus controls. A change in the relative frequency of reinforcement associated with one of several successive stimuli changes the rate of responding during that stimulus; an increase in relative frequency produces an increase in the rate of responding. For example, suppose that responding is reinforced on a VI 3-minute schedule during the presentation of both red and green keys and then reinforced on VI 3 minutes only during the presentation of red. The relative frequency of reinforcement associated with red increases. Before the change in schedule, 0.5 of the total reinforcers per session occurred when the key was red. After the change, the same *absolute* number of reinforcers occurs in red; but since none occurs in green, the relative frequency in red increases to 1.0. The increase in relative frequency of reinforcement from 0.5 to 1.0 results in contrast, an increase in the rate of responding.

The relative frequency of reinforcement during red does not increase when DRO reinforcements are delivered during green. The histograms in Fig. 3 show that more than 30 reinforcers (the average frequency in a session on VI 3 minutes) occur per session with the DRO schedule. Since the frequency of reinforcement associated with red is maintained at a constant value, the relative frequency during red declines when the frequency in green increases. The rate of responding during red does not increase (VI-to-DRO curve, Fig. 4).

SUMMARY

A pigeon's rate of key pecking during the presentation of one stimulus was modified by changing only the schedule of reinforcement associated with a *different* stimulus. Typically, the rate of responding increases in the component of a multiple schedule whose schedule is maintained as reinforcement when the schedule in the other component is changed from reinforcement to extinction. The present experiments show that, in addition, a time out (no lights in the experimental chamber and no reinforcements), which immediately produces a near-zero rate of responding, also results in an increase in the rate of responding in the other component. Both extinction and time out produce a lower rate of responding and fewer reinforcements than does a VI schedule. In order to separate the effects of not responding from the effects of no reinforcement, food was presented when no responses occurred for 50 seconds during extinction or time out. Reinforcement for not responding, concurrent with extinction or time out in one component, produced very low rates of responding but maintained a high frequency of food presentations. Under these conditions, the increase in the rate of responding on the VI schedule in the other component (behavioral contrast) was eliminated.

REFERENCES

Azrin, N. H. Some effects of two intermittent schedules of immediate and non-immediate punishment. *J. gen. Psychol.*, 1956, **42**, 3-21.

Estes, W. K., and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **39**, 466-483.

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

Findley, J. D. Preference and switching under concurrent scheduling. *J. exp. anal. Behav.*, 1958, **1**, 123-145.

Hanson, H. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-335.

Herrick, R. M., Myers, J. L., and Korotkin, A. L. Changes in S^D and S^Δ rates during the development of an operant discrimination. *J. comp. physiol. Psychol.*, 1959, **52**, 359-364.

Herrnstein, R. J., and Morse, W. H. Some effects of response-independent positive reinforcement on maintained operant behavior. *J. comp. physiol. Psychol.*, 1957, **50**, 461-467.

Pavlov, I. P. *Conditioned reflexes.* Trans. G. V. Anrep. Oxford, 1927.

Reynolds, G. S. An analysis of interactions in a multiple schedule. Unpublished doctoral dissertation, Harvard Univer., 1960.

Schuster, C. Response latencies as a measure of the interaction of components in a multiple fixed-ratio schedule. *J. exp. anal. Behav.*, 1959, **2**, 259. (Abstract).

Skinner, B. F. *The behavior of organisms.* New York: Appleton Century Co., 1938.

Smith, M. H., and Hoy, W. J. Rate of response during operant discrimination. *J. exp. Psychol.*, 1954, **48**, 259-264.

Solomon, R. L. Latency of response as a measure of learning in a "single-door" discrimination. *Amer. J. Psychol.*, 1943, **56**, 422-432.

Verplanck, W. S. The development of a discrimination in a simple locomotor habit. *J. exp. Psychol.*, 1942, **31**, 441-464.

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