

*CONTRAST AND INDUCTION IN MULTIPLE
SCHEDULES OF DISCRETE-TRIAL
CONCURRENT REINFORCEMENT*

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Three pigeons were exposed to two-key discrete-trial concurrent schedules of reinforcement. Red and white key colors alternated irregularly and the assignment of reinforcers depended on key color. The red-key schedules were held constant, with the scheduled relative frequency of reinforcement for left-key pecks set at 0.75, while the white-key schedules varied. When the location of white-key reinforcement was changed from one side to the other, while its overall frequency was constant, red-key choices shifted in the same direction as white-key choices, an induction effect. When the overall frequency of white-key reinforcement was changed while its location remained constant, red key choices shifted in a direction opposite to white-key choices, a contrast effect. Both induction and contrast effects were clearer when the overall frequency of red-key reinforcement was reduced. These data demonstrate that the allocation of responding may exhibit schedule interaction effects similar to those commonly reported for response rate.

Key words: behavioral contrast, induction, multiple schedules, concurrent schedules, choice, key peck, pigeons

When different stimulus conditions successively signal independent reinforcement conditions, as in multiple schedules, changing the reinforcement conditions in one component (the varied component) affects responding in the alternated (constant) component, even though scheduled reinforcement conditions in the latter are unchanged (for review, see Mackintosh, 1974; Schwartz and Gamzu, 1977). When responding in the constant component changes in a direction opposite to that in the varied component, the result is termed contrast; if responding changes in the same direction, the result is termed induction (Reynolds, 1961). The analysis of steady-state contrast and induction effects in multiple schedules has relied exclusively on single-response procedures, with response rate, latency, or time spent responding as dependent variables. Here, we extend the demonstration and analysis of

contrast and induction in multiple schedules to the allocation of responding across alternatives in a choice situation. To accomplish this extension, the usual single response in each component is replaced with two simultaneously available response alternatives, maintained by concurrent schedules of reinforcement. The concurrent schedules in the constant component are left unchanged, while the overall rate of reinforcement and the relative rate of reinforcement for the response alternatives in the varied component are manipulated systematically. If response allocation in the constant component shifts in a direction opposite to that in the varied component, the result is classified as contrast; if in the same direction, the result is classified as induction.

The present experiment explored these kinds of interactions in discrete-trial concurrent variable-interval variable-interval (VI VI) schedules (*cf.* Nevin, 1969). By using discrete-trial rather than continuous free-operant schedules, the two stimulus conditions signaling the different concurrent VIs could be alternated rapidly and irregularly from trial to trial, thus maximizing their interaction. We manipulated both the overall and relative probabilities of food reinforcement per trial in the varied component, and isolated some determiners of contrast and induction effects

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in the allocation of responding in the constant component.

METHOD

Subjects

Three male White Carneaux pigeons, which had previously served in studies of matching-to-sample and chained-schedule performance, were maintained at 80% of their free-feeding body weights ± 15 g.

Apparatus

The experiment was conducted in a standard two-key Lehigh Valley pigeon chamber, with the keys separated by 12.7 cm, center to center. The grain magazine was located centrally beneath the keys, and a houselight was located centrally above the keys. Conventional electromechanical programming and recording equipment was in an adjacent room.

Procedure

After a 6-sec intertrial interval, during which the keys were dark and responding had no effect, both keys were lighted the same color. The constant component was correlated with red keylights, and the varied component with white. The first peck on either key turned off both keylights and started the 6-sec intertrial interval. Reinforcers (2.25-sec presentations of the grain magazine) occasionally followed pecks, but did not prolong the intertrial interval. Key colors changed irregularly from trial to trial according to a quasi-random sequence that arranged equal frequencies of red and white in every 50-trial block, with no runs of either color longer than three. The houselight was on throughout daily sessions of 200 trials.

Reinforcers were scheduled by a probability generator in series with a randomly wired 50-point stepping switch. On any given trial, determined by the stepping switch, reinforcement was arranged for either the left key or the right key with some probability, depending on the key color. Once arranged, the reinforcer remained available for a peck at that key and color until collected, and the program continued to assign reinforcers on subsequent trials whether a given reinforcer was collected or not. For example, a reinforcer assigned to the right key on a red-key trial remained available until the bird pecked the right key on a red-

key trial. No additional reinforcers could be assigned to the right key given red, but they were assigned to the left key given red, or to either key given white, with probabilities that were constant from trial to trial. This program is equivalent to the use of four independent variable-interval (VI) scheduling tapes with constant-probability distributions of interreinforcement time or, equivalently, four random-interval schedules as programmed by Millenson (1963).

The scheduled probabilities of reinforcement per trial for the left and right keys, given red and white keylights, are listed in Table 1, together with the number of training sessions at each set of reinforcement probabilities.

The experiment began with identical schedules in the presence of red and white, with reinforcement probabilities of 0.24 and 0.08 on the left and right keys, respectively. This provided a baseline of nondifferential reinforcement with respect to the key colors, analogous to the standard multiple VI VI baseline in the study of free-operant contrast effects. In the second condition, reinforcement probabilities in the presence of white were reversed to produce a shift in the allocation of white-key responding, with no change in overall reinforcement probability. Because there was no evidence of sustained interactions in responding to red, we arranged a more extreme change in the white-key schedule, shifting from probabilities of 0.08 and 0.24 on the left and right keys respectively to 1.00 and 0.00. This shift altered the overall probability of white-key reinforcement from 0.32 to 1.00, while at the same time altering the location of the richer schedule from right to left. These two factors were separated in subsequent conditions, which included transitions in which the location of white-key reinforcement was changed from one side to the other while its probability remained constant (Conditions 3 to 4, 5 to 6, 9 to 10, and 14 to 15), and also transitions in which the probability of white-key reinforcement was changed while its location remained constant (Conditions 4 to 5, 8 to 9, and 15 to 16). Condition 7 replicated Condition 4, where the transition from Condition 6 involved changes in both location and probability of white-key reinforcement. Conditions 8 through 10 and 14 through 16 employed the same relative probabilities of reinforcement in the presence of red as the earlier conditions,

Table 1

Probability of reinforcement availability per trial for pecks to the left and right keys when the keys were lighted red or white during successive conditions of the experiment. Proportion of pecks to the left key, and numbers of reinforcers obtained on both keys and colors are also presented for the final five sessions of each condition.

Condition	Sessions	Probability of Reinforcement				Proportion of Left Pecks		Reinforcers Obtained			
		Red		White		Red	White	Red		White	
		Left	Right	Left	Right			Left	Right	Left	Right
BIRD 90											
1	100	0.24	0.08	0.24	0.08	0.76	0.81	122	27	111	35
2	50	0.24	0.08	0.08	0.24	0.87	0.29	130	19	31	107
3	15	0.24	0.08	1.00	0	0.99	0.99	114	6	485	0
4	15	0.24	0.08	0	1.00	0.89	0.02	120	20	0	488
5	15	0.24	0.08	0	0.08	0.86	0.14	131	25	0	38
6	15	0.24	0.08	0.08	0	0.85	0.86	115	27	36	0
7	15*	0.24	0.08	0	1.00	—	—	—	—	—	—
8	15	0.12	0.04	0	1.00	0.74	0.00	65	11	0	488
9	15	0.12	0.04	0	0.08	0.70	0.20	58	15	0	26
10	15	0.12	0.04	0.08	0	0.82	0.72	56	19	34	0
11	15	no red key		0	1.00	—	0.02	—	—	0	481
12	15	no red key		0	0.08	—	0.15	—	—	0	45
13	15	no red key		0.08	0	—	0.79	—	—	55	0
14	15	0.12	0.04	0.08	0	0.85	0.87	65	12	41	0
15	15	0.12	0.04	0	0.08	0.73	0.22	57	22	0	38
16	15	0.12	0.04	0	1.00	0.83	0.00	64	10	0	491
BIRD 91											
1	100	0.24	0.08	0.24	0.08	0.86	0.84	126	21	124	22
2	50	0.24	0.08	0.08	0.24	0.79	0.53	129	25	34	102
3	15	0.24	0.08	1.00	0	0.99	0.99	129	3	492	0
4	15	0.24	0.08	0	1.00	0.87	0.02	122	22	0	483
5	15	0.24	0.08	0	0.08	0.90	0.51	130	17	0	34
6	15	0.24	0.08	0.08	0	0.88	0.90	128	20	44	0
7	15	0.24	0.08	0	1.00	0.88	0.00	118	24	0	494
8	15	0.12	0.04	0	1.00	0.82	0.01	61	15	0	488
9	15	0.12	0.04	0	0.08	0.73	0.14	62	11	0	30
10	15	0.12	0.04	0.08	0	0.90	0.85	66	10	36	0
11	15	no red key		0	1.00	—	0.03	—	—	0	486
12	15	no red key		0	0.08	—	0.10	—	—	0	42
13	15	no red key		0.08	0	—	0.96	—	—	48	0
14	15	0.12	0.04	0.08	0	0.95	0.98	66	4	49	0
15	15	0.12	0.04	0	0.08	0.51	0.28	51	25	0	50
16	15	0.12	0.04	0	1.00	0.87	0.03	60	13	0	482
BIRD 93											
1	100	0.24	0.08	0.24	0.08	0.78	0.73	119	33	107	35
2	50	0.24	0.08	0.08	0.24	0.68	0.23	113	29	24	126
3	15	0.24	0.08	1.00	0	0.99	0.98	127	3	491	0
4	15	0.24	0.08	0	1.00	0.96	0.02	122	12	0	481
5	15	0.24	0.08	0	0.08	0.64	0.28	116	37	0	30
6	15	0.24	0.08	0.08	0	0.74	0.92	122	26	34	0
7	15	0.24	0.08	0	1.00	0.84	0.02	124	21	0	489
8	15	0.12	0.04	0	1.00	0.79	0.02	68	14	0	487
9	15	0.12	0.04	0	0.08	0.73	0.10	54	23	0	38
10	15	0.12	0.04	0.08	0	0.76	0.79	64	13	30	0
11	15	no red key		0	1.00	—	0.01	—	—	0	496
12	15	no red key		0	0.08	—	0.24	—	—	0	36
13	15	no red key		0.08	0	—	0.91	—	—	37	0
14	15	0.12	0.04	0.08	0	0.86	0.96	60	19	51	0
15	15	0.12	0.04	0	0.08	0.51	0.29	50	19	0	40
16	15	0.12	0.04	0	1.00	0.88	0.02	58	14	0	486

*Data not available for Bird #90 because of recording failure.

but their values were reduced from 0.24 and 0.08 to 0.12 and 0.04. This change was based on free-operant data indicating that infrequently reinforced responding is more sensitive to behavioral interactions (Spealman and Gollub, 1974). Finally, Conditions 11 through 13 were included to determine whether the effects of changing the white-key schedules were dependent on the presence of red-key trials and their associated reinforcement schedules. During these three conditions, sessions consisted of 100 white-key trials only.

RESULTS

The allocation of responding to the left and right keys, given red or white keylights, stabilized slowly during the initial condition, with

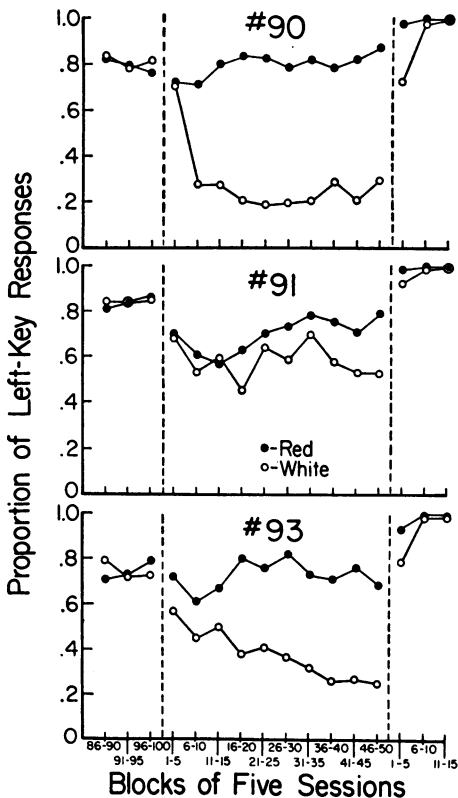


Fig. 1. Proportion of left-key responses in the presence of red or white during the last 15 of 100 sessions of Condition 1, all 50 sessions of Condition 2, and all 15 sessions of Condition 3, in five-session blocks. Red-key responding was always reinforced with probability 0.24 on the left and 0.08 on the right. The white-key reinforcement probabilities were 0.24 and 0.08 in Condition 1, 0.08 and 0.24 in Condition 2, and 1.00 and 0 in Condition 3, for the left and right keys respectively.

little change in session-to-session variability after Session 60. The proportion of responses to the left key in the presence of red and white during each of the last 15 sessions of Condition 1, and throughout Condition 2 (50 sessions) and Condition 3 (15 sessions) is shown for the three birds in Figure 1. In Condition 1, all three birds approximately matched the proportion of left-key pecks to the proportion of left-key reinforcers obtained. When the white-key schedules were reversed in Condition 2 to favor the right key, Bird #90 shifted its white-key responding almost at once, while Bird #91 never shifted fully to the right key. Bird #93 was intermediate. All three birds exhibited transitory induction effects in red-key responding. The magnitude and duration of the induction effects were correlated with the rate at which the birds altered the allocation of responding to the white keys. There was no convincing evidence of contrast or induction effects by the end of Condition 2.

In Condition 3, when the probability of reinforcement for pecking the left white key was abruptly shifted to 1.0, the proportion of left-key pecks increased immediately in the presence of both red and white for all birds. This is evidence of an induction effect. Although the nearly total concentration of responding on the left red key meant that the proportion of reinforcers obtained for left red pecks departed appreciably from scheduled values, it is unlikely that this factor was directly responsible for the abrupt shift in responding, because in the immediately preceding condition, a much larger change in obtained reinforcement on the white keys had only gradual effects for at least two birds. Once the shift to left-key pecking occurred, however, it may have been maintained by the consequent alteration in the ratio of obtained reinforcers.

The remainder of this analysis concentrates on performance during the final five sessions of each condition. Mean proportions of left-key pecks are summarized for all subjects and conditions in Table 1; Figure 2 presents the relation between the mean and the unbiased estimate of the standard error of the proportion over the final five sessions. The solid line in Figure 2 indicates the expected standard error of 100-trial samples as a function of the probability of a left-key peck, assuming Bernoulli trials—that is, each trial ends with either a left- or right-key peck, and the probability of

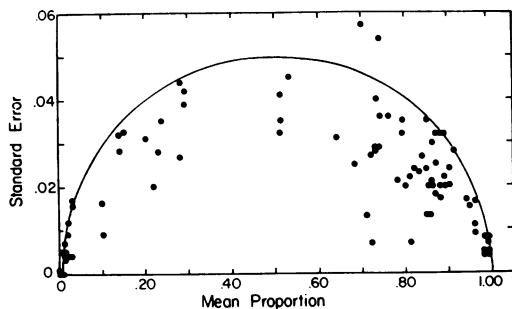


Fig. 2. The standard error of the proportion of left-key responses during the final five sessions of each condition as related to the mean proportion, for both red and white keys for all subjects. The solid line represents the relation expected if responding were generated by a Bernoulli-trials process.

a left-key peck is independent of responses or outcomes on preceding trials. The large majority of points fall below expectation, suggesting that the Bernoulli-trials assumption is not correct. Most likely, there were some dependencies within sequences of trials. In any case, the overall proportions summarized in Table 1 are based on five-session samples, which, if anything, are less variable than a Bernoulli process, with standard errors rarely exceeding 0.04.

Figure 3 displays the effects of transitions in which the probability of white-key rein-

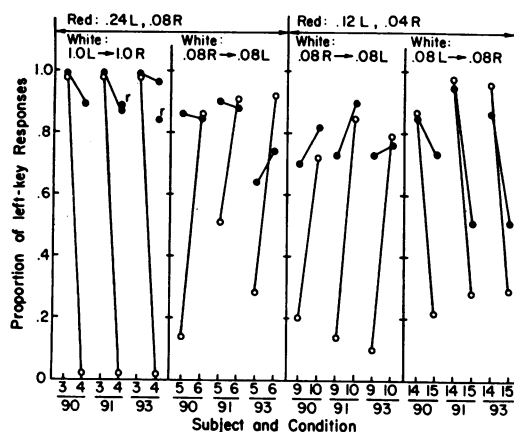


Fig. 3. Proportion of left-key responses during the final five sessions of successive conditions in which the scheduled probability of white-key reinforcement remained constant, while its location was shifted from one side key to the other, as indicated in each panel. Red-key schedules are indicated above the appropriate panels. Results are displayed separately for red (filled circles) and white (unfilled circles), as indicated for each subject and condition. The points labelled "r" are from Condition 7, which replicated Condition 4.

forcement was held constant, while its location was changed from one side key to the other. The first panel (comparing Conditions 3 and 4) shows small but consistent induction effects when white-key reinforcement was scheduled with probability 1.0 on one key. The points labelled "r" in the figure are from Condition 7, which replicated Condition 4 with reasonable success. The second panel (comparing Conditions 5 and 6) shows inconsistent effects when white-key reinforcement was scheduled with probability 0.08. When the probabilities of red-key reinforcement were reduced, in Conditions 9, 10, 14, and 15, consistent induction effects appeared as shown in the third and fourth panels.

In addition to exhibiting induction effects when the location of white-key reinforcement was changed, Figure 3 also suggests another sort of interaction, in that the proportion of pecks on the left red key was generally lower when the probability of white-key reinforcement was 0.08 than when it was 1.0, regardless of its location. Figure 4 displays the effects of changing white-key reinforcement probability on one key while reinforcement probability on the other key remained 0.0.

The first panel of Figure 4 (comparing Conditions 4 and 5) shows that the proportion of pecks to the left white key increased when the probability of reinforcement was reduced from 1.0 to 0.08, even though left-key pecking was never reinforced when the keys were white. This shift was accompanied by a clear contrast effect in red-key responding by Bird 93, and little effect in the others. The second and third panels show that when the probabilities of red-key reinforcement were reduced in Conditions 8, 9, 15, and 16, consistent contrast effects were exhibited regardless of order of reinforcement probabilities.

As mentioned above, our induction and contrast effects may be byproducts of shifts in obtained relative reinforcement frequency, despite constancy of the scheduled relative reinforcement probabilities in the presence of red. Figure 5 plots the ratio of left-key to right-key responses in relation to the ratio of obtained left-key to right-key reinforcers during red-key trials, for the last five sessions of all conditions presented in Figures 3 and 4. Clearly, there is a positive correlation here, and our results may be confounded in part by shifts in obtained reinforcement when responding

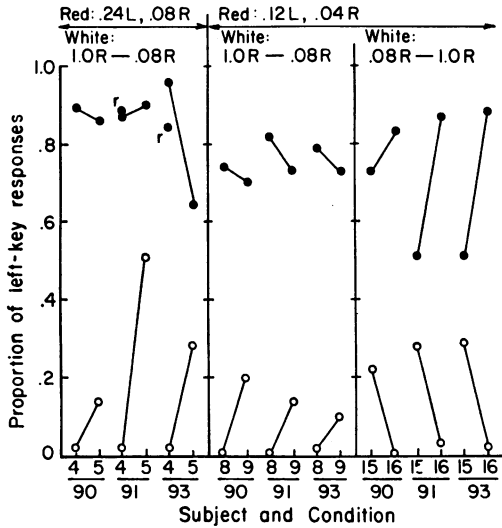


Fig. 4. Proportion of left-key responses for the final five sessions of successive conditions in which the location of white-key reinforcement remained constant while its scheduled probability varied, as indicated in each panel. Red-key schedules are indicated above the appropriate panels. Results are displayed separately for red (filled circles) and white (unfilled circles), as indicated for each subject and condition. The points labelled "r" are from Condition 7, which replicated Condition 4.

changes. However, response ratios change over a wider range than reinforcement ratios and the slope of the relation is clearly greater than

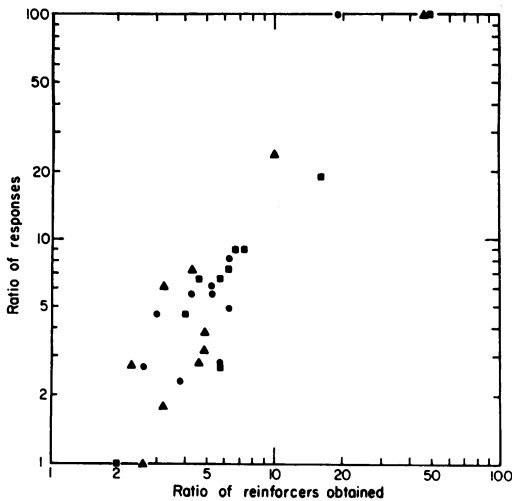


Fig. 5. The ratio of left-key responses to right-key responses on red-key trials is plotted on logarithmic coordinates in relation to the ratio of left-key reinforcers to right-key reinforcers obtained on those trials. Data are presented for each subject, for all conditions represented in Figures 3 and 4.

1.0. Slopes computed by Isaac's (1970) method, Case 3, were 2.05, 1.42, and 1.52 for Birds 90, 91, and 93, respectively. All three slopes were significantly different from 1.0 ($p < 0.01$). If we had explicitly manipulated reinforcement ratios, this result would be termed "overmatching" (Baum, 1974), an outcome which to our knowledge has never been systematically demonstrated in research on concurrent VI VI schedules (cf. Myers and Myers, 1977). Accordingly, we conclude that the induction and contrast effects in these data are not mere by-products of any tendency for the allocation of responding to match the allocation of reinforcers.

The shift in white-key pecking when the probability of reinforcement was reduced, despite constancy of the relative frequency of reinforcement (always 0.0 or 1.0), was confirmed in Conditions 11, 12, and 13, which excluded red-key trials. As summarized in Figure 6, the effects of white-key schedule changes on the allocation of white-key responding were independent of whether or not red-key trials were scheduled, or what the overall reinforcement density was in the presence of red. These average data are representative of the results for individual subjects, although the individual data are more variable, as shown in Figures 3 and 4.

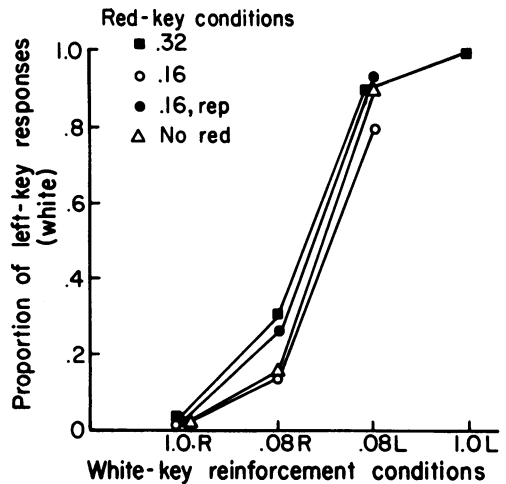


Fig. 6. Proportion of left-key responses on white-key trials, in relation to the various conditions of reinforcement arranged when the keys were white, as indicated along the x-axis. Data are means for all three subjects, for the red-key reinforcement conditions indicated.

DISCUSSION

Two major effects appear in the present data, most clearly when the overall probability of reinforcement in red was low: (a) When the overall probability of white-key reinforcement was held constant while its location changed from one key to the other, white-key choices shifted appropriately and red-key choices shifted in the same direction—an induction effect. (b) When the location of white-key reinforcement remained constant but its overall probability was changed, the reinforced white key was chosen more or less often as the probability of reinforcement changed up or down, while red-key choices shifted in the opposite direction—a contrast effect.

The induction effects are not entirely surprising. Consider what would happen if the nominal stimuli "red" and "white" were indiscriminable to the subjects. Then, clearly, changing the location of "white"-key reinforcement would produce identical shifts in responding to both "red" and "white"; that is, complete induction. Our nominal stimuli were certainly discriminated, but there are features common to both red- and white-key trials—*e.g.*, abrupt onset of keylights in identical locations after an intertrial interval—which may have promoted some generalization between them, and hence induction when white-key reinforcement was changed from one side to the other.

The contrast effects are less easy to understand, in part because of the absence of prior data on contrast with choice allocation as the dependent measure. Only one such experiment is known to us. Eisenberger, Frank, and Park (1975) trained rats in a straight alley with 16 food pellets per trial, and then reduced the amount of reinforcement to two pellets. In a free-choice test, the rats chose the training alley less often than a control group that had two pellets throughout training. In a second experiment, rats initially trained with one pellet and then shifted to eight pellets chose the training alley more often than a control group that received eight pellets throughout training. These effects are instances of "successive incentive contrast", which has been reviewed by Mackintosh (1974). These contrast effects appear immediately after unsignalled shifts in amount of reinforcement, and their determiners may have little in common with the

factors controlling interactions during prolonged exposure to signalled differential reinforcement conditions, as in the present study.

The two most prominent current accounts of contrast during exposure to signalled differential reinforcement invoke shifts in the relative rate of reinforcement, or in stimulus-reinforcer contingencies. These accounts were originally distinguished by Rachlin (1973), and have been applied to contrast effects in the rate of a free operant in multiple and concurrent schedules by a number of writers. When the rate of reinforcement in the varied component of a multiple schedule is decreased, increases in response rate may be explained by either account. The general formulation proposed by Herrnstein (1970) relates the rate of responding to the relative rate of reinforcement; contrast in multiple schedules is an instance of this general relation. The alternative view of contrast in multiple schedules emphasizes responses elicited by stimulus-reinforcer contingencies: when the reinforcement rate in the varied component is reduced, the resultant change in the correlation between the constant-component stimulus and reinforcement elicits responses that summate with those maintained by the constant-component schedule to give contrast (for a thorough review of this approach, see Schwartz and Gamzu, 1977). Elicited pecking is assumed not to be relevant to concurrent-schedule responding, however (Rachlin, 1973). Increases in the rate of responding on one key of a concurrent schedule pair when the rate of reinforcement on the other key is reduced are simply explained by the relation between response rate and relative reinforcement rate.

Our procedure might best be viewed as a multiple schedule composed of a number of brief presentations of two concurrent schedules. We did not measure changes in the absolute rate of response, but rather in the relative frequency of pecking to one side key over a series of discrete trials. Although it may be possible to construct an account of our data based on differential tendencies to approach a key resulting from stimulus-reinforcer contingencies, it is difficult to interpret our data in terms of the summation of elicited and operant key-pecking. It may, however, be instructive to consider our contrast data in relation to Herrnstein's formulation based on relative rate of reinforcement.

In our procedure, as in all two-key forced-choice procedures, the probabilities of pecking the left and right keys must sum to 1.0. Therefore, if right-key responding is increased, left-key responding must decrease. When white-key reinforcement density is changed, however, reinforcement rate in red relative to total reinforcement changes in the same direction for both left and right keys. Specifically, if reinforcement density in white is reduced, then there is a corresponding increase in relative reinforcement rate on both keys in red. The problem is illustrated in Figure 7, which shows the average proportion of pecks on the left key, and the complementary proportion of pecks on the right key on red-key trials, as a function of the average proportion of all reinforcers obtained for left- or right-key pecks on red trials. The data points are labelled by condition, and pairs of points determined under similar conditions (except for the density of red-key reinforcement) are connected. When white-key reinforcement increases, resulting in a decrease in relative reinforcement for both left and right keys on red trials, the allocation of red-key responding becomes more extreme. Although right-key responding is related to relative reinforcement as expected, left-key responding perforce changes in the opposite direction. It is not clear that either response has any special status that would permit a prior decision as to which response is directly affected by relative reinforcement. Accordingly, an account of our data in terms of reinforcement for one response in one key color, relative to total reinforcement, is difficult to construct.

A third possible account of contrast effects is suggested by our (Nevin, 1974) conception of response strength as the resistance of responding to change. In one study, pigeons were trained on multiple schedules with VI 1-min and VI 3-min components, separated by dark-key periods during which response-independent reinforcers could be presented. When the rate of dark-key reinforcement increased, the rate of responding in the VI 1-min component decreased less than in the VI 3-min component, suggesting that more frequent reinforcement established greater resistance to change. Extinction, satiation, and conditioned suppression procedures have yielded similar findings with both greater frequency and

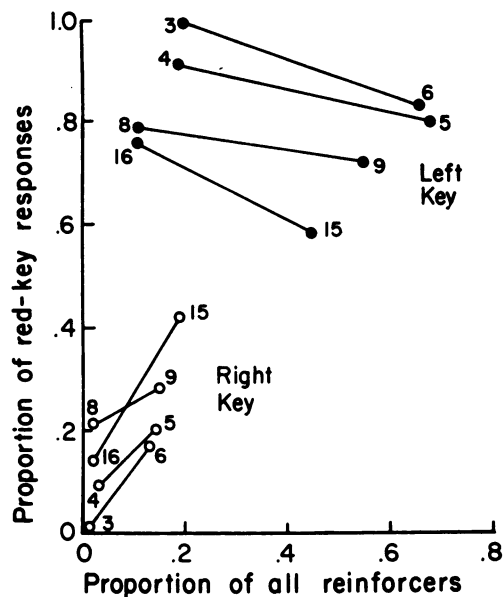


Fig. 7. For red-key trials, the proportion of left-key responses, and the complementary proportion of right-key responses, are plotted as a function of the number of reinforcers obtained for pecking the left or right keys when they were red, relative to all reinforcers obtained in both red-key and white-key trials. Lines connect pairs of points for which the red-key schedules and the location of white-key reinforcement were the same so that the only variable was the probability (and thus obtained frequency) of white-key reinforcement. The data are averages for all three birds.

amount of reinforcement establishing greater resistance to change (see Nevin, 1974, for review.) Spealman and Gollub's contrast data are also consistent with this general conclusion: they found that contrast effects were larger for a group of birds shifted from multiple VI 180-sec VI 180-sec to multiple VI 180-sec extinction than for a group shifted from multiple VI 30-sec VI 30-sec to multiple VI 30-sec extinction. Thus, responding maintained by the VI 30-sec schedule was more resistant to contrast-producing changes in the alternated component than was responding maintained by the VI 180-sec schedule. Note that our account does not specify the factors responsible for contrast; rather, it groups contrast together with a variety of operations that alter response rates, including extinction, satiation, and conditioned suppression, and notes some commonalities among their behavioral effects.

There have been very few studies of resistance to change using concurrent-schedule

baselines. DeVilliers and Millenson (1972) trained rats on concurrent schedules differing in amount of reinforcement, and then superimposed a signal correlated with response-independent electric shock. Responding decreased much less on the lever correlated with the larger reinforcer, resulting in a substantial preference shift toward the favored lever in the presence of the signal. Similar data were reported by Leslie and Millenson (1973), employing a signal correlated with response-independent food. In both studies, then, the response obtaining the greater amount of reinforcement was more resistant to change, and the resultant preference shift may be construed as a byproduct of this fact.

The contrast data of our present study are also consistent with this account. For example, when the density of reinforcement for white-key responding increased, responding to the left red key, which was more frequently reinforced, should be more resistant to change than responding to the right key. Thus, the tendency to peck the left key would decrease less than the tendency to peck the right key, leading to a shift in preference to the left key, as observed.

An account of our contrast effects in terms of resistance to change must remain speculative at present. It is silent on why induction occurred when the density of white-key reinforcement remained unchanged while its location was shifted. Also there was no direct measure of the overall tendency to peck in the presence of red (*e.g.*, latency to the peck in the various experimental conditions). Nevertheless, our account has the advantage of integrating our contrast data with those of single-response free-operant studies, and providing an alternative to the relative-reinforcement or induced-pecking accounts that presently dominate the literature on behavioral contrast.

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