*DISCRIMINATIVE STIMULUS LOCATION AS A
DETERMINANT OF POSITIVE AND NEGATIVE
BEHAVIORAL CONTRAST IN THE PIGEON¹*

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Four pigeons were exposed to a series of two-component multiple schedules of reinforcement that ordinarily yield positive and negative behavioral contrast. The stimuli that signalled the component schedules were sometimes located on the response key and sometimes off. Positive behavioral contrast was observed only when the stimuli were on the key. Negative contrast was observed independent of stimulus location. These data suggest that positive and negative contrast may be causally unrelated, and support an account of contrast in terms of the summation of key pecks that are separately controlled by response-reinforcer and stimulus-reinforcer dependencies.

The study of key pecking in pigeons has traditionally emphasized the influence of response-dependent reinforcement. However, substantial recent research on autoshaping and related phenomena has indicated that key pecking is both established and maintained if a differential predictive relationship exists between response-key illumination and food, even when food delivery is independent of responding (Brown and Jenkins, 1968; Gamzu and Schwartz, 1973; Gamzu and Williams, 1971, 1973; Schwartz, 1973), or dependent on not responding (Schwartz and Williams, 1972; Williams and Williams, 1969). The powerful control of key pecking by a stimulus (key-light)-reinforcer dependency in the absence of a response-reinforcer dependency raises questions about the effects of stimulus-reinforcer and response-reinforcer dependencies in combination. One situation in which both types of dependency are present is the multiple-schedule procedure. A multiple schedule is one in which the component schedules are in force successively, each in the presence of a different external stimulus. Thus, for example, in a

multiple variable-interval extinction schedule (*mult* VI EXT), reinforcement depends upon both the key peck and the presence of the stimulus correlated with the VI schedule.

Gamzu and Schwartz (1973) extended findings from autoshaping experiments to the analysis of multiple-schedule performance. One of the more striking phenomena observed with multiple schedules is positive behavioral contrast (*e.g.*, Reynolds, 1961). If a procedure is changed from *mult* VI VI to *mult* VI EXT, decreases in responding in the presence of the extinction stimulus are accompanied by increases in responding in the presence of the VI stimulus. Gamzu and Schwartz suggested that positive contrast depends upon independent contributions to the rate of key pecking by both stimulus-reinforcer and response-reinforcer dependencies. Consider the *mult* VI VI schedule. Here, the response-reinforcer dependency exerts control over key pecking. However, since both discriminative stimuli signal reinforcement availability, there is no differential stimulus-reinforcer dependency also to contribute to rate of pecking. When the schedule is changed to *mult* VI EXT, the response-reinforcer dependency continues to maintain a given response rate. Now, however, there is also a differential stimulus-reinforcer dependency. This dependency may also maintain a given rate of pecking and the two rates may simply combine, with positive contrast as the result.

A number of predictions follow from this "additivity theory" of contrast (Schwartz and Gamzu, *in press*). First, consider an experiment

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in which treadle hopping in pigeons is maintained on a multiple schedule. When the schedule is shifted from *mult VI VI* to *mult VI EXT*, a differential stimulus-reinforcer relation is introduced. This relation might be expected to generate and maintain pecking. However, the required operant is not pecking, but treadle hopping. Thus, the joint effect of stimulus-reinforcer and response-reinforcer relations would not result in an increase in operant responding. Rather, if the behavior controlled by the stimulus-reinforcer dependency competes with treadle hopping, one might expect a decrease in treadle hopping (negative induction), rather than an increase (positive contrast). Studies by Westbrook (1973) and Hemmes (1973) confirmed this prediction.

Now consider an experiment in which key pecking is reinforced on a multiple schedule, but the stimuli that signal the components of the multiple schedule are not located on the response key. Again, when the procedure is changed from *mult VI VI* to *mult VI EXT*, a differential stimulus-reinforcer dependency is introduced. However, the behavior controlled by this dependency will be directed at the VI signal, which is not on the key. As a result, one would not expect summation of behavior controlled by stimulus-reinforcer and response-reinforcer dependencies, and thus, one would not expect to observe positive contrast. Studies by Redford and Perkins (1974) and Schwartz (1974) supported this prediction. On the other hand, Westbrook (1973) and Hemmes (1973) did observe some positive contrast in procedures of this type. A part of the present experiment was designed to replicate earlier findings (Schwartz, 1974) and perhaps resolve this uncertainty in the literature.

Consider a final experiment. Key pecking is reinforced on a *mult VI 3-min, VI 3-min* schedule. The procedure is then changed to *mult VI 3-min VI 1-min*. Responding in the VI 1-min component increases, not surprisingly. Also, however, responding in the unchanged VI 3-min component decreases. This phenomenon is called negative behavioral contrast. There is substantial evidence of negative contrast with pigeons as subjects (Bloomfield, 1967; Nevin, 1968; Reynolds, 1963; Terrace, 1966; Zuriff, 1970). How does the additivity theory of contrast account for negative contrast? The change from *mult VI 3-min VI 3-min* to *mult VI 3-min VI 1-min* introduces a

differential stimulus-reinforcer relation. To account for decreases in VI 3-min responding, however, one must argue that the stimulus-reinforcer relation inhibits pecking, rather than enhancing it. This is a difficult argument. If the stimulus-reinforcer relation makes no contribution to pecking on a *mult VI 3-min VI 3-min* schedule, what can it be inhibiting on a *mult VI 3-min VI 1-min* schedule? The additivity theory of contrast seems to require that negative contrast be treated as a phenomenon that is unrelated to positive contrast, and controlled by other variables. If this is true, then one might expect manipulations that influence the occurrence of positive contrast to leave negative contrast unaffected. For example, if pigeons are exposed to a series of multiple schedules in which the location of the stimuli signalling the components is varied, one might expect positive contrast to occur only if the stimuli are located on the response key, while the occurrence of negative contrast might be independent of stimulus location.

The present experiment examined this possibility. Pigeons were first exposed to a series of multiple-schedule procedures that ordinarily result in positive contrast. The stimuli that signalled the components of the multiple schedule were sometimes on the key, sometimes houselight illumination, sometimes auditory, and sometimes located on a second key. Keller (1974) showed in this last case that contrast does not occur on the operant key, but that responses are directed at the key on which the signals are presented. Summation of responses on both keys synthesizes positive contrast, an elegant confirmation of the additivity theory. In a second phase of the present experiment, the pigeons were exposed to a series of multiple-schedule procedures that would ordinarily result in negative contrast. Again, the location of the stimuli that signalled the schedule components was varied. The predictions that follow from the additivity theory of contrast are that first, positive contrast would occur only when the signal stimuli were on the response key, and second, negative contrast would occur independent of stimulus location.

METHOD

Subjects

Two Silver King and two White Carneaux male pigeons were maintained at 80% of free-

feeding weights; both were experimentally naive.

Apparatus

Two keys of a three-key Lehigh Valley Pigeon Panel (Model No. LVI519C) could be illuminated with either green, white, or blue light. The feeder was located below the center key and the houselight was located above the key. A shield directed the houselight toward the ceiling of the chamber. A sound source (2800 Hz Sonalert), in series with a 1000-Ohm resistor was located to the right of the feeder. During reinforcement, 4-sec access to mixed grain, a light in the feeder was illuminated and all other chamber lights were extinguished.

Procedure

The pigeons were first trained to approach and eat from the food magazine. After one session of magazine training, the pigeons were trained to peck the center response key (illuminated by white light), by the method of successive approximation. During the first session of key-peck training, a variable-interval 30-sec (VI 30-sec) schedule of reinforcement was introduced. Food was available after varying intervals of time, with a mean of 30 sec, dependent upon a key peck. During the second session, a VI 1-min schedule was introduced, and the pigeons were exposed to three 60-min sessions of VI 1-min reinforcement, after which the experiment proper began.

The experimental procedure consisted of a series of two-component multiple schedules of reinforcement. Each daily session consisted of 36, 100-sec components, with the two schedules alternated regularly. The procedures were of three types: some of the multiple schedules consisted of identical VI schedule components, some consisted of unequal VI schedule components, and some consisted of a VI schedule component and an extinction (EXT) component, during which no food was delivered. The stimuli used to signal the two-component schedules were varied from one procedure to the next. The component schedules, the stimuli employed, and the number of sessions of each procedure are shown in Table 1. The procedures are best viewed in pairs. The first member of each pair (A1, B1, C1, *etc.*) was a multiple schedule with equal VI components. In the second member of each pair (A2, B2,

C2, *etc.*), one of the component schedules was changed while the other schedule and the stimulus conditions were unaltered. Procedures A2, B2, C2, and F2 were designed to produce positive contrast. Procedures D2 and E2 were designed to produce negative contrast. In procedures B and D, the signals for the multiple-schedule components were different colored illuminations of the center key. In procedure A, the signals for the components were the presence or absence of the houselight. In procedure C, the signals were the presence or absence of the Sonalert. In procedures A and C, the center key was always white. Finally, in procedures E and F, the component signals were different colors on a side key. In these procedures, the center key was always blue. Responses on the side key were counted, but had no scheduled consequences. In all phases of the experiment, reinforcement depended upon pecks on the center key.

RESULTS

It was predicted in the introduction that positive behavioral contrast would be observed only when the stimuli that signalled the two components of the multiple schedule were located on the response key. The relevant data (from procedures A, B, and C) are presented in Figure 1. Rates of responding in the VI component of the *mult* VI 1-min EXT and *mult* EXT VI 1-min schedules are plotted as a proportion of asymptotic rate during the same VI schedule in the preceding *mult* VI 1-min VI 1-min schedules. Points above the dashed horizontal lines indicate positive contrast. Points below those lines indicate negative induction. The results are uniform. Positive contrast was observed in all subjects only when green and blue center-key colors signalled the multiple-schedule components. When houselight illumination or Sonalert were signals, there was no sign of contrast.

Session-to-session response rates in both multiple-schedule components for Pigeon 4 are presented in Figure 2. The absence of contrast in any but the fourth panel is clear. Also evident is the fact that discrimination proceeded rapidly, independent of the stimuli employed to signal the multiple-schedule components.

It was also predicted in the introduction that negative behavioral contrast would be independent of the stimuli employed to signal

Fig. 1. Response rate in the unchanged VI component of a multiple VI 1-min EXT schedule as a proportion of asymptotic response rate in a preceding multiple VI 1-min VI 1-min schedule. Session-to-session proportions are plotted separately for each pigeon. Each panel is labelled by the stimulus that signalled the multiple-schedule components. Points above the dashed horizontal lines indicate positive behavioral contrast. Points below the lines indicate negative induction. A number of sessions of multiple VI 1-min VI 1-min training intervened between each of the panels in this figure.

the multiple-schedule components. The relevant data are presented in Figure 3, which has the same format as Figure 1, and includes data from procedures D and E. Here, points below the dashed horizontal line indicate negative contrast; points above the line indicate positive induction. When center-key colors signalled the multiple-schedule components, large negative contrast effects were observed, though Pigeons 1 and 3 showed brief positive induction. When the multiple-schedule components were signalled on a second key, negative contrast was observed in three of four pigeons. Pigeon 1 showed a smaller (though substantial) negative contrast effect than previously, but it disappeared by the fourteenth session. Pigeon 2 showed as much negative con-

trast as previously. Pigeon 3 showed positive induction. Pigeon 4 showed as large a negative contrast effect as before, but it did not begin to appear until the eighth session.

Figure 4 presents session-to-session response rates for Pigeon 4 on these procedures. It can be seen that the change from VI 3-min to VI 72-sec when the signals were located on the response key (second panel) produced substantial increases in response rate, along with concomitant decreases in rate in the unchanged VI 3-min component. Similar findings are presented in the fourth panel. Here, the signalling stimuli were located on a second key. Response rate on the center key increased on the VI 72-sec schedule relative to the VI 3-min response rate. In addition, the pigeon be-

Fig. 2. Session-to-session response rate in each component of the multiple schedules across all procedures depicted in Figure 1, for Pigeon 4. The multiple schedules and associated stimuli are identified in each panel (e.g., in the second panel, Stim 1 is H/L on, correlated with extinction).

gan pecking at the signal key when it signalled the VI 72-sec schedule. This responding did not develop until the seventh session, which is just before negative contrast began to appear on the center key. It should be noted that virtually no responding was directed at the signal key when it signalled the VI 3-min schedule, and that no responding at all occurred to the signal key in the preceding *mult* VI 3-min VI 3-min (third panel).

The right-hand portion of Table 1 presents responses per minute in each multiple-schedule component for each pigeon across all the procedures. The data are averaged across the last five sessions of each procedure. Numbers in parentheses are rates of responding on the signal key when it was present. Instances of positive and negative contrast are indicated by asterisks. Most of these data have been captured in the figures described. However, the data from the last two procedures have not been presented graphically. The shift from *mult* VI 72-sec VI 72-sec to *mult* EXT VI 72-sec did not increase responding on the center

key during the VI component. The response rate of Pigeons 1 and 3 increased by about two responses per minute, and the response rates of Pigeons 2 and 4 decreased by about that amount. However, substantial amounts of responding were directed at the VI signal. The pigeons responded on the white signal key between 11 and 18 times per minute. If these response rates are added to center-key response rate, and the sum is divided by asymptotic response rate in the preceding procedure (analogous to Figures 1 and 3), the resulting ratios for Pigeons 1 to 4 respectively are 1.29, 1.23, 1.39, and 1.37. Thus, all four pigeons show large positive contrast effects only if signal key pecks are included in computation. These data replicate those reported by Keller (1974).

DISCUSSION

In the present experiment, positive behavioral contrast occurred only when the stimulus that signalled the VI component of a

Table 1
Summary of Procedures and Responses Per Minute over the Last Five Sessions of Each Procedure for Each Pigeon

Responses per Minute over Last Five Sessions												
Sched. 1	Sched. 2	Stim. 1	Stim. 2	# Sess.	P1		P2		P3		P4	
					Stim. 1	Stim. 2	Stim. 1	Stim. 2	Stim. 1	Stim. 2	Stim. 1	Stim. 2
A1	VI 1-min	H/L on	H/L off	21	42.5	44.0	35.6	35.6	46.0	46.2	42.1	42.6
A2	EXT	H/L on	H/L off	14	5.4	42.2	3.3	34.9	7.8	46.1	3.7	41.4
B1	VI 1-min	Green	Blue	21	43.6	42.0	36.8	37.0	45.4	46.0	41.3	41.4
B2	VI 1-min	Green	Blue	14	59.8*	2.9	45.9*	2.1	61.8*	5.8	62.2*	3.2
C1	VI 1-min	Tone off	Tone on	21	42.5	43.0	35.6	36.8	47.2	46.6	43.6	44.1
C2	EXT	Tone off	Tone on	14	6.7	41.9	4.3	35.6	6.9	46.2	6.8	42.0
D1	VI 3-min	Green	White	15	34.4	31.2	23.6	26.0	25.2	31.0	33.1	37.2
D2	VI 3-min	Green	White	14	18.1**	44.8	19.4**	46.4	22.3**	46.0	26.8**	47.4
E1	VI 3-min	Blue (Green signal)	Blue (White signal)	18	37.8 (0.0)	39.4 (0.0)	42.6 (0.0)	44.0 (0.0)	28.1 (0.0)	26.2 (0.0)	37.4 (0.0)	38.6 (0.0)
E2	VI 3-min	Blue (Green signal)	Blue (White signal)	21	28.6 (0.08)**	47.6 (8.4)	26.8 (0.1)**	39.2 (9.2)	30.8 (0.0)	45.4 (4.3)	28.2 (1.2)**	48.1 (7.1)
F1	VI 72-sec	Blue (Green signal)	Blue (White signal)	21	42.6 (0.0)	44.3 (0.0)	42.4 (0.0)	45.6 (0.0)	44.8 (0.0)	46.3 (0.0)	47.6 (0.2)	46.4 (0.1)
F2	EXT	Blue (Green signal)	Blue (White signal)	21	3.8 (0.7)	46.1* (11.3)	4.1 (0.9)	43.2* (12.7)	6.9 (1.4)	48.2* (16.3)	4.7 (3.4)	45.3* (18.2)

*Positive contrast.
**Negative contrast.
Numbers in parentheses indicate response rates on the signal key.

Fig. 3. Response rate in the unchanged VI component of a multiple VI 3-min VI 72-sec schedule as a proportion of asymptotic response rate in a preceding multiple VI 3-min VI 3-min schedule. Points below the dashed horizontal lines indicate negative contrast. Points above the lines indicate positive induction. See legend of Figure 1 for further details.

mult VI EXT schedule was located on the response key. When houselight and tone were employed as signals, no contrast was observed. When a separate key was employed to signal multiple-schedule components, responses on the signal key and the operant key combined synthesized behavioral contrast, but there was no sign of contrast on the operant key itself. On the other hand, negative behavioral contrast was observed whether the multiple-schedule components were signalled on the operant key or on a separate key.

It is unlikely that any of the present findings are attributable to the specific discriminative stimuli or sequence of procedures employed. In procedure A2, the multiple-schedule component that might have yielded positive contrast was signalled by the absence of a stimulus (houselight), while in procedure C2, that component was signalled by the presence of a stimulus (tone). Moreover, in a previous experiment (Schwartz, 1974), the presence of a houselight and the absence of a tone signalled components that might have yielded positive

Fig. 4. Session-to-session response rate in each component of the multiple schedule across all procedures depicted in Figure 3, for Pigeon 4. Open circles in the fourth panel depict response rate on the signal key when it was illuminated with white light, and signalled a VI 72-sec schedule on the operant key. See legend of Figure 2 for further details.

contrast, with results similar to the present ones. It should also be noted that discrimination between components of the multiple schedule was clear and effective independent of the particular discriminative stimuli employed.

Thus, it appears that the present results support the view of behavioral contrast proposed by Gamzu and Schwartz (1973). That view may be summarized as follows: whenever a dependency exists between a response and a reinforcer, the reinforcer will maintain the response. Similarly, whenever a dependency exists between a stimulus and a reinforcer, presentation of the stimulus will generate and maintain behavior. In the case of the pigeon, the behavior maintained by a key-food dependency is pecking, and pecks are directed at the stimulus (Brown and Jenkins, 1968; Gamzu and Williams, 1971, 1973). As a result, with key pecking as the response in the response-reinforcer dependency, and the key as the

stimulus in the stimulus-reinforcer dependency, as in procedure B of the present study (Table 1), these two sources of control of behavior sum, producing positive behavioral contrast.

However, positive contrast is not an inevitable consequence of multiple-schedule procedures. It depends upon the procedural coincidence that both stimulus-reinforcer and response-reinforcer relations direct behavior toward the key. When the stimulus-reinforcer dependency does not serve this function, as in procedures A, C, and F of the present experiment (Table 1), no contrast is observed. Similar findings have been obtained by Schwartz (1974) and by Redford and Perkins (1974). On the other hand, Hemmes (1973) and Westbrook (1973) observed positive contrast under similar conditions. There is no obvious way to reconcile these different results. Westbrook did not observe contrast in all subjects and the contrast effects he did observe were smaller than

the effects usually observed when the signals are on the response key. Moreover, some of the pigeons in Westbrook's experiment that did not show contrast also showed very little evidence of discrimination when a multiple-schedule component was changed from VI to EXT. In Hemmes' study, however, both discrimination and contrast were clear cut. Hemmes employed different colored houselights as signals, rather than presence *versus* absence of houselight, as in the present study (procedure A) and the Schwartz (1974) study. This might account for the observed behavioral differences. However, Redford and Perkins (1974) also employed different colored houselights as signals and failed to observe contrast. Whatever the resolution of this discrepancy in the literature may turn out to be, the present data provide clear support for the additivity theory of contrast. These data, together with the evidence that pigeons do not show positive contrast when treadle hopping rather than key pecking is the operant (Hemmes, 1973; Westbrook, 1973), make it clear that a complete account of positive contrast will have to include a consideration of the interaction of stimulus-reinforcer and response-reinforcer dependencies.

With respect to negative behavioral contrast, the situation is more complex. Negative contrast is demonstrated when responding in the unchanged component of a multiple schedule decreases with increases in responding in the other component (procedures D and E). The additivity theory of contrast does not seem applicable to negative contrast. Consider a *mult* VI 3-min VI 3-min schedule. Under these conditions, there is no differential stimulus-reinforcer relation. Thus, one would expect the contribution of the stimulus-reinforcer relation to rate of key pecking to be about zero. When the procedure is changed to *mult* VI 3-min VI 72-sec, response rate in the VI 3-min component decreases. If the contribution of the stimulus-reinforcer relation previously was zero, it is hard to account for the decrease in responding in the VI 3-min component in terms of an inhibitory stimulus-reinforcer relation. The problem faced by such an account is identifying what could be inhibited. For negative contrast to be explained as the product of an inhibitory stimulus-reinforcer relation, it is necessary to argue that an excitatory relation exists under conditions of

equal VI schedules, an argument that previous research (Gamzu and Schwartz, 1973; Schwartz, 1973) makes unlikely. Thus, the additivity theory seems compelled to argue that positive and negative contrast are at least partly unrelated. The present data support this position. The occurrence of negative contrast (unlike positive contrast) was independent of the location of the stimuli that signalled the multiple-schedule components. There are, however, two strong arguments, one empirical and one logical, for treating positive and negative contrast as two sides of the same coin. Empirically, there is strong evidence that the phenomena referred to here as positive and negative contrast fall quantitatively on a single linear function that relates relative rate of responding to relative frequency of reinforcement (*e.g.*, Nevin, 1973, p. 221). Indeed, it has been argued that these phenomena are merely instances of the matching law, which relates response rate to reinforcement rate in simple, multiple, and concurrent schedules of reinforcement (Herrnstein, 1970). The logical relation between positive and negative contrast has been pointed out by Rachlin (1973).

It can best be discussed by illustration. Suppose a pigeon is exposed to a *mult* VI 3-min VI 3-min procedure, and then to a *mult* VI 3-min VI 6-min procedure. Response rate in the unchanged VI 3-min component increases. Before we can call this increase contrast, it must be shown that when the procedure is returned to *mult* VI 3-min VI 3-min, responding in the unchanged component returns to its previous level. Suppose that it does. Rachlin argues that this is an instance of negative contrast. Responding in one component of a multiple schedule decreases with increases in responding (and reinforcement frequency) in the other component. Thus, a rigorous demonstration of positive contrast entails a concomitant demonstration of negative contrast. From an additivity theory of contrast, the observed decrease in VI 3-min responding would be explained in terms of the elimination of the differential stimulus-reinforcer contingency that produced positive contrast in the preceding procedure. Suppose, however, that an additional procedure, a *mult* VI 3-min VI 1-min schedule, was run. Decreases in responding now on the VI 3-min schedule (negative contrast) could not be explained by the additivity theory of contrast in the same way. There are

two possible means of reconciling Rachlin's arguments with the additivity theory of contrast. The first is to argue that procedure changes from equal to unequal schedules have different effects than procedure changes from unequal to equal schedules. The second, and perhaps more appealing possibility, is to argue that even under conditions of equal VI multiple schedules, there is a differential excitatory stimulus-reinforcer relation. Both of the stimuli that signal the two components of the multiple schedule predict food in contrast to extra-apparatus stimuli that predict no food. If one grants this premise, it is necessary to make the additional argument that when the procedure is changed to a multiple schedule with unequal VI components, the stimulus that signals the less-dense schedule becomes inhibitory. In support of this possibility, Weisman (1969) observed that when pigeons were shifted from *mult* VI 1-min VI 1-min to *mult* VI 1-min VI 5-min, positive contrast occurred in the unchanged VI component, and in the changed VI component inhibitory generalization gradients were obtained. Also, Rilling, Askew, Ahlskog, and Kramer (1969) showed that pigeons will peck a key to escape from the VI 5-min component of a *mult* VI 5-min VI 30-sec schedule. Though these studies are suggestive, both the logical and empirical relationships between negative and positive contrast require further investigation.

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