CONTRAST AND INDUCTION IN RATS ON MULTIPLE SCHEDULES¹

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Eight rats were trained on a variable-interval schedule in the presence of a light (Phase I). Responding was then extinguished in the presence of darkness that alternated with the light (Phase II). Reinforcement was then introduced in the presence of darkness (Phase III). Several rats were then returned to the condition of Phase II (Phase IV) and then to that of Phase III (Phase V). The responding of most rats showed clear behavioral contrast in Phase II—*i.e.*, an increase in responding in the presence of the light. When, for three rats, Phase III was introduced early after the occurrence of positive contrast, either positive induction occurred, *i.e.*, an increase in responding in the presence of the light, or there was little change. Negative contrast did not occur. It was further shown that positive contrast dissipates over time, thus replicating a result previously obtained with pigeons and that the positive induction effect seems also to dissipate over time. The introduction of reinforcement in the presence of darkness (Phases III and V) after the dissipation of positive contrast seemed to have little consistent effect.

Reynolds (1961*b*) defined the following types of interactions in multiple schedules:

Positive contrast. An increase in response rate in one component as a function of a decrease in response rate in a second component.

Negative contrast. A decrease in response rate in one component as a function of an increase in a second component.

Positive induction. An increase in response rate in one component as a function of an increase in a second component.

Negative induction. A decrease in response rate in one component as a function of a decrease in a second component.

With pigeons, at least, it has typically been found (*e.g.*, Reynolds, 1961*a*, *b*) that positive contrast will occur in two-component multiple schedules when response rate is decreased in one component by decreasing the reinforcement frequency in that component; and, that negative contrast will occur when response rate is increased in one component by increasing the reinforcement frequency in that com-

ponent. There are certain exceptions to these generalizations. For example, Reynolds (1963) found that induction, rather than contrast, may result from small changes in a low frequency of reinforcement in one component; Terrace (1963*a*) has shown that contrast is not produced when a discrimination is developed by means of his errorless method.

There exist few data on the occurrence of contrast in species other than pigeons. Positive contrast in rats has been obtained by Smith and Hoy (1954), and by Herrick, Myers, and Korotkin (1959). However, there are no studies demonstrating negative contrast in rats similar to the above pigeon studies.

Pear and Wilkie (1969) reported an experiment in which two rats were tested on a somewhat modified multiple schedule. The schedule contained two components. The onset of one component was signalled by stimulus change (*i.e.*, the houselight alternately changed from "off" to "on" and from "on" to "off"), but no discriminative event signalled the onset of the second component. Originally, responding in both components was reinforced on a variable-interval 30-sec (VI 30-sec) schedule. Then the second component was changed to extinction (Ext). After several sessions, VI 30-sec was reintroduced in the second component. Several such alternations were conducted for each rat. It was found that positive

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contrast generally, though not always, occurred when extinction was carried out in the second component. However, negative contrast was not observed when VI 30-sec was reintroduced in the second component. Indeed, on several such occasions, positive induction occurred.

The results of the above study appear to limit the generality of the negative contrast effect. This raises the question of what relevant aspects of its procedure differed from those of studies in which negative contrast was obtained. Among the possibilities are the use of rats rather than pigeons and the use of a non-standard multiple schedule. The primary purpose of the present experiment was to test for this latter possibility.

METHOD

Subjects

Eight Holtzman male albino rats were maintained at 80% adjusted free-feeding weight, with the adjustments based on the normal growth curve reported by Ezinga and Becker (*in press*). Their ages, in days, at the beginning of the experiment were: 125 (S52, S53, S54, S55); 166 (S71, S72, S73), and 129 (S74).

Apparatus

The experimental space consisted of a standard Lehigh Valley Electronics test chamber, Model 1316, mounted in a Model 1316C cubicle. The inside dimensions of the test cage measured 7.5 in. high, 12 in. wide, and 8 in. deep (18.75 by 30 by 20 cm). A lever was mounted 1.75 in. (4.5 cm) above the grid on the left-hand side of one 8 in. (20 cm) wall. Operation of the lever required approximately 24 gm (0.235 N) force to operate. A 6-w house light served a stimulus function. No other source of illumination was provided. An exhaust fan in the cubicle and air conditioning inlets in the room housing the experimental space provided a masking noise.

Food reinforcers, consisting of 0.01 ml of a mixture of Borden's sweetened condensed milk and tap water (50% of each by volume), were delivered by a solenoid-operated dipper. The dipper protruded into the experimental space at the bottom of the same wall on which the lever was located.

Standard relay-operated scheduling and recording equipment was located in a nearby room.

Procedure

Over about twelve 1-hr sessions the subjects were gradually adjusted to a VI 30-sec schedule, constructed from a rectangular probability distribution in which the maximum interval was 60 sec. The houselight was on throughout each session. The data from the first 9 min of each session was discounted as warm-up time.

After four 1-hr sessions on VI 30-sec, sessions were lengthened to 2 hr. At about the same time, a change in the mode of operating the dipper was made for four of the subjects. Previously the dipper was operated from the normally up position. This was changed to the normally down position for S71, S72, S73, and S74. For these subjects, the dipper rested in the milk reservoir until a reinforced response was emitted. The dipper was then presented for 3 sec and returned to the reservoir. For the other subjects, the dipper continued to operate from the normally up position. When a reinforced response was emitted, the dipper plunged into the milk reservoir and returned, the cycle being completed in about 0.5 sec.

The experiment consisted of five phases, although not all subjects were exposed to the last one or two phases. These phases, and the number of 2-hr sessions received in each by each subject, are shown in Table 1. In Phase I, VI 30-sec was in effect and the houselight was on throughout every session. In Phase II, multiple (*mult*) VI 30-sec Ext was introduced in which each component lasted 5 min and the houselight was off during the second component.

Table 1
Summary of Experimental Conditions

Phase	Schedule	Number of Sessions							
		S52	S53	S54	S55	S71	S72	S73	S74
I	VI 30-sec	14	14	14	14	32	32	23	24
II	<i>mult</i> VI 30 Ext	7	31	30	6	63	14	6	4
III	<i>mult</i> VI 30 VI 30	24	23	28	25	12	18	62	78
IV	<i>mult</i> VI 30 Ext	60	—	—	58	—	5	—	—
V	<i>mult</i> VI 30 VI 30	8	—	—	—	—	15	—	—

In Phase III, *mult VI* 30-sec VI 30-sec was introduced either after a short period or after a long period of exposure to Phase II. The purpose was to determine the effects of introducing reinforcement in the second component both before and after positive contrast had dissipated. (Terrace [1966] showed that positive contrast in pigeons will dissipate after prolonged discrimination training.)

Finally, Phases IV and V consisted of reintroducing *mult VI* 30-sec Ext and *mult VI* 30-sec VI 30-sec, respectively.

RESULTS

The basic strategy was first to attempt to produce positive contrast by introducing *mult VI* 30-sec Ext after obtaining stability on VI 30-sec; then to introduce *mult VI* 30-sec VI

30-sec either (1) during the positive contrast effect, or (2) after positive contrast had dissipated. The results are therefore described for each subject in terms of when *mult VI* VI was first introduced after obtaining positive contrast on *mult VI* Ext. A third category is included for two subjects for which positive contrast was not demonstrated.

(1) *Mult VI* VI first introduced during the positive contrast effect on *mult VI* Ext. The mean response rate per session in each phase of the experiment for the three subjects included in this category—S52, S55, and S74—is shown in Fig. 1. Note that each of these subjects shows a clear increase above baseline in the first component upon the introduction of *mult VI* Ext.

For S52, there was a sharp increase in responding in the second component upon the

Fig. 1. Response rates during each phase for animals in which *mult VI* VI (Phase III) was first introduced during the positive contrast effect on *mult VI* Ext (Phase II). The dashed line is the mean response rate over the last five sessions of Phase I. Although only one component was in effect during Phase I, the data have been presented as though both components were in effect in order to facilitate comparing the phases. Thus, the two curves in Phase I represent different time samples of an invariant procedure.

introduction of *mult VI VI* in Phase III. Responding in the first component, which was increasing at the end of Phase II, continued to increase for some time afterwards and then remained fairly steady at a high level. In Phase IV of the experiment for S52, *mult VI Ext* was reintroduced. Note from Fig. 1 that there appears to have been a slight increase in first-component response rate, followed by a rapid return to its level in the previous phase. Eventually, responding in the first component decreased to the baseline level of Phase I. When *mult VI VI* was reintroduced in Phase V, there was little or no change in responding in the first component. That is, the positive induction effect that appeared to have occurred in Phase III did not occur in Phase V. This suggests that induction is weaker after contrast has dissipated, a suggestion that will receive further support from results described in the next section.

S55—like S52 above—showed a sharp increase in responding in the second component upon the introduction of *mult VI VI* in Phase III. Unlike the case for S52, however, there was no apparent tendency for first-component responding to increase in Phase III. Neither, however, did it decrease towards the baseline level of Phase I, *i.e.*, there was no negative contrast effect. Instead, it appears to have stabilized at about the level it achieved in Phase II. Upon the introduction of *mult VI Ext*, S55—like S52—showed a slight increase in responding in the first component followed by a rapid return to the level in the previous phase. As was the case for S52, first-component responding eventually decreased to the baseline level of Phase I.

S74 also showed a sharp increase in responding in the second component upon the introduction of *mult VI VI* in Phase III. At the same time there was a dramatic increase in responding in the first component. Over a number of sessions, responding in this component then decreased to approximately its level in Phases I and II. This was followed by another, even greater, increase that is difficult to account for. However, responding in the first component eventually returned again to approximately the baseline level of VI 30-sec responding in Phase I.

The main results for the above subjects may be summarized as follows: When *mult VI 30-sec Ext* was changed to *mult VI 30-sec VI 30-sec*

while positive contrast was occurring, response rate in the first component either increased or remained the same. Negative contrast did not occur. When *mult VI Ext* was reintroduced for two subjects (S52 and S55), both showed a slight increase in the first component, followed by a decrease to the previous level. This was then followed after a number of sessions by a decrease to the VI 30-sec baseline of Phase I. The third subject, S74, also showed an eventual first-component decrease to the original VI 30-sec baseline even though continued on *mult VI VI*.

(2) *Mult VI VI first introduced after dissipation of positive contrast on mult VI Ext.* The mean response rate per session in each phase of the experiment for the three subjects included in this category—S53, S54, and S71—are shown in Fig. 2. Note that S53 and S71 show a clear increase above baseline in the first component upon the introduction of *mult VI Ext*. The result for S54 is by no means clear; however, the rates at the points labelled “a” and “b”, which exceed any of the rates during baseline, may be taken as some evidence of a slight and short-lived increase over baseline responding.

If S54 can be considered to have shown positive contrast, note that with continued exposure to *mult VI Ext* all three subjects show an eventual decrease in the first component to approximately their original baseline levels in Phase I. Upon the introduction of *mult VI VI* in Phase III, there were no consistent changes across subjects in first-component responding. S71 showed a decrease in first-component responding upon the introduction of *mult VI VI*. But this statement does not appear to hold for S53 or S54. The results of the latter two subjects compare favorably with those of S52, which also showed no clear change in first-component responding when *mult VI VI* was reintroduced in Phase V after the dissipation of positive contrast (see Fig. 1). It should be noted that these results differ from those of Reynolds and Limpo (1968) who, working with pigeons, consistently obtained negative contrast after the dissipation of positive contrast.

(3) *Mult VI VI first introduced after failure to demonstrate positive contrast on mult VI Ext.* The mean response rates per session in each phase of the experiment of the two subjects included in this category—S72 and S73—are shown in Fig. 3.

Fig. 2. Response rates during each phase for animals in which *mult VI VI* (Phase III) was first introduced after the dissipation of positive contrast on *mult VI Ext* (Phase II). The dashed line is the mean response rate over the last five sessions of Phase I. Although only one component was in effect during Phase I, the data have been presented as though both components were in effect in order to facilitate comparing the phases.

S72 is a special case because of the pronounced variability in its baseline during Phase I. Thus, it is difficult to decide whether or not there was an increase in first-component responding when *mult VI Ext* was introduced in Phase II. In addition, there were no obviously consistent changes in first-component responding in the subsequent phases of the experiment.

For S73 there was likewise no noticeable change in first-component responding (except for increased variability) upon the introduction of *mult VI Ext* in Phase II; even though in this case baseline responding in Phase I was quite stable. The failure to obtain positive contrast in this case may have been related to the extremely rapid decrease in the second component. Upon the introduction of *mult VI VI* (Phase III), there was a sharp increase in

second-component responding, as there was for the other subjects in this experiment. Initially, there was a slight decrease in first-component responding, but it lasted for only a few sessions and was followed by a relatively steady increase. Over a large number of sessions, response rate in the first component returned to and stabilized at approximately the original baseline level of Phase I. This eventual return to baseline seems to have held true for all the subjects regardless of whatever other effects resulted from the various manipulations.

DISCUSSION

It appears from these results that positive contrast will occur for at least some rats when *VI 30-sec* is changed to *mult VI 30-sec Ext*.

Fig. 3. Response rates during each phase for animals in which *mult VI VI* (Phase III) was first introduced after failure to demonstrate positive contrast on *mult VI Ext* (Phase II). The dashed line is the mean response rate over the last five sessions of Phase I. Although only one component was in effect during Phase I, the data have been presented as though both components were in effect in order to facilitate comparing the phases.

Another conclusion supported by the present results is that if discrimination training on *mult VI* 30-sec Ext is carried out long enough, positive contrast will gradually decrease so that response rate in the first component will approximate the initial baseline level. This extends the generality of a similar finding with pigeons by Terrace (1966).

The occurrence of positive induction in several instances and the general failure to observe negative contrast is in accord with the results of Pear and Wilkie (1969) mentioned in the Introduction, and indicates that their results are not specific to the non-standard multiple schedule they used. Wilkie (1970) also obtained data that support this conclusion. At least one other case has been reported in which negative contrast did not occur under conditions that might have been expected to produce it. Bloomfield (1967), using pigeons, obtained positive contrast when *mult VI VI* was changed to *mult VI Ext*. However, upon reinstating *mult VI VI* the rate in the first component remained at the level it had attained during positive contrast. He then reintroduced *mult VI Ext* and observed a second positive contrast effect. Upon the reintroduction of *mult VI VI*, negative contrast occurred;

i.e., responding in the first component returned to the level attained during the immediately preceding exposure to that schedule.

The initial failure to obtain negative contrast by Bloomfield (1967) with pigeons, and the occurrence of positive induction in rats in our laboratory, may be due in some way to weak stimulus control. Bloomfield used a line-tilt discrimination, whereas most other studies on contrast in pigeons have used color discriminations. A line-tilt discrimination may be more difficult than a color discrimination. Indeed, in another study, Bloomfield (1966) found that a line-tilt discrimination developed more slowly than did a red-green discrimination. Moreover, Terrace (1963*b*) reported difficulty developing an errorless line-tilt discrimination with the same technique he had used to develop an errorless color discrimination. To accomplish the former he had first to establish a color discrimination, then superimpose the lines on the colors and gradually fade out the colors.

It may be that in the present experiment darkness exerted very weak control over not responding. Note how quickly the response rate increased in the second component when *mult VI Ext* was changed to *mult VI VI* (Fig.

1 to 3). Although responding did decrease rapidly in the second component when darkness was first introduced, the novelty of this stimulus may have been an important factor in this effect.

Why should weak stimulus control lead to positive contrast but not to negative contrast? Assume that when stimulus control is strong, contrast tends to occur, but when it is weak induction tends to occur (see Wertheim, 1965). Note that during *mult VI Ext* two cues differentiate the first component from the second; *viz.*, the positive stimulus and the occurrence of reinforcers. The fact that reinforcement can act as a discriminative stimulus (*e.g.*, Reid, 1957) should make the discrimination relatively easy, even if the explicit stimulus is exerting weak control, and the tendency for contrast to occur should be correspondingly strong. But upon returning to *mult VI VI* the occurrence of reinforcement no longer differentiates the two components, and the discrimination is thus more difficult. Hence, the tendency for induction is increased and this competes with the negative contrast effect. It appears that in some instances, perhaps especially when the second component is made particularly difficult to discriminate (Pear and Wilkie, 1969), the tendency towards positive induction is considerably stronger than that towards negative contrast, and predominates.

Several aspects of the data appear to be consistent with this interpretation. First, as mentioned, the rapid increase in responding in the second component when *mult VI Ext* was changed to *mult VI VI* suggests that darkness did not exert much control over not responding. Second, the extreme intersession variability during both *mult VI Ext* and *mult VI VI* suggests the interaction of two opposing processes; *viz.*, contrast and induction. Third, induction tended to be less strong after prolonged discrimination training: it could be that prolonged discrimination training enhanced the discrimination; or, alternatively, that the tendency for positive induction dissipated simultaneously with the dissipation of positive contrast. Finally, the fact that positive contrast did not always occur might indicate that, due to weak stimulus control, it was cancelled out by a tendency towards negative induction. Certain aspects of data obtained by Pierrel, Sherman, Blue, and Hegge (1970) may be relevant here; working with rats on tone

discriminations, these investigators found evidence of positive contrast only when the discriminative stimulus associated with reinforcement was at least 40 db greater than the discriminative stimulus associated with extinction.

The above considerations are speculative but they are testable in principle by means of experiments in which the degree of stimulus control is varied (*e.g.*, see Wertheim, 1965).

In conclusion, the present results extend the generality of two findings with pigeons. They indicate that positive contrast can occur in rats, and that this effect dissipates with extended discrimination training. However, the results also raise questions about the generality of the negative contrast effect.

REFERENCES

- Bloomfield, T. M. Two types of behavioral contrast in discrimination learning. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 155-161.
- Bloomfield, T. M. Some temporal properties of behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 159-164.
- Ezinga, G. and Becker, G. Is hunger drive held constant in the behavior experiment employing fixed food-deprivation schedules? *Psychological Reports*, in press.
- Herrick, R. M., Myers, J. L., and Korotkin, A. L. Changes in S^D and S^A rates during the development of an operant discrimination. *Journal of Comparative and Physiological Psychology*, 1959, 52, 359-364.
- Pear, J. J. and Wilkie, D. M. Stimulus change as a discriminative event in a semimultiple schedule. *Proceedings, 77th Annual Convention, APA*, 1969, pp. 797-798.
- Pierrel, R., Sherman, J. G., Blue, S., and Hegge, W. Auditory discrimination: a three-variable analysis of intensity effect. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 17-35.
- Reid, R. L. The role of the reinforcer as a stimulus. *British Journal of Psychology*, 1957, 49, 292-309.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 57-71. (a)
- Reynolds, G. S. An analysis of interactions in a multiple schedule. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 107-117. (b)
- Reynolds, G. S. Some limitations on behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 131-139.
- Reynolds, G. S. and Limpo, A. J. Negative contrast after prolonged discrimination maintenance. *Psychonomic Science*, 1968, 10, 323-324.
- Smith, M. H. and Hoy, W. J. Rate of response during operant discrimination. *Journal of Experimental Psychology*, 1954, 48, 259-264.
- Terrace, H. S. Discrimination learning with and without errors. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 1-27. (a)

- Terrace, H. S. Errorless transfer of a discrimination across two continua. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 223-232. (b)
- Terrace, H. S. Behavioral contrast and the peak shift: effects of extended discrimination training. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 613-617.
- Wertheim, G. A. Behavioral contrast during multiple avoidance schedules. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 269-278.
- Wilkie, D. M. *On some determinants of behavioral contrast*. Unpublished doctoral dissertation, University of Manitoba, Winnipeg, Canada, 1970.
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