STIMULUS-SPECIFIC CONTRAST EFFECTS DURING OPERANT DISCRIMINATION LEARNING¹

JOHN C. MALONE, JR.

UNIVERSITY OF TENNESSEE, KNOXVILLE

In two experiments, pigeons' responding was equally reinforced in the presence of four line-orientation stimuli. Responding was then reinforced when only two of the four orientation stimuli were present; the remaining two orientations appeared during extinction. Response rates were often highest in the stimulus adjacent to the orientations presented during extinction and often lowest in that orientation adjacent to the orientations presented with reinforcement. These effects were stronger and more persistent when the stimuli were separated by a smaller angle, rendering the discrimination more difficult. These and other data suggest that discrimination training may not be accurately explained in terms of the simple effects of reinforcement and nonreinforcement associated with isolated stimuli, nor by accounts that depend upon stimulus generalization. Recent accounts of contrast that depend upon "emotionality" produced by nonreinforced responding or upon reinforcement-elicited responses are also difficult to apply to these data.

Key words: successive discrimination, behavioral contrast, multiple schedule, variable interval, key peck, pigeons

When responding is reinforced or not reinforced in the presence of some stimulus, changes in response rates in other stimuli often occur. Almost invariably, these changes are attributed to "induction" or "stimulus generalization". These terms provide a name for the "induced" changes in responding and are sometimes presumed to provide an explanation for the effects. The use of stimulus generalization as a basic explanatory principle has been popular for some time and continues to be standard practice (*e.g.*, Hearst, Besley, and Farthing, 1970; Pavlov, 1927; Skinner, 1938; Spence, 1937; Terrace, 1966).

Behavioral contrast, first treated by Skinner (1938, p. 175), refers to an effect that is not readily explained in terms of stimulus generalization. Contrast appears as a change in response rate in one component of a multiple schedule as a consequence of a change in conditions in another component or components. The direction of this change is opposite to the change in responding in the second compo-

nent. For example, response rate in a variable-interval (VI) component increases when the schedule in an alternated component is changed from VI to extinction (EXT) and decreases when this change is reversed. Thus, contrast represents a divergence in response rates, rather than the covariation in responding which defines stimulus generalization.

Since Reynolds' (1961) demonstration that contrast is a reliable effect accompanying the formation of a discrimination, most research has been directed at specifying the necessary and sufficient conditions for contrast. Reynolds suggested that contrast depends upon the relative reinforcement frequency associated with components, while others such as Terrace (*e.g.*, 1963, 1966) argue that contrast is a by-product of the "emotional" effect arising from the aversiveness of stimuli correlated with unreinforced responding. This issue remains unresolved; contrast occurs when relative reinforcement frequency remains constant and other variables are manipulated (*e.g.*, Terrace, 1968) as well as when the possibility for the occurrence of unreinforced responding is precluded (*e.g.*, Reynolds, 1961).

Since Reynolds' original demonstration of contrast, very little has been done to assess the contribution of stimulus factors to the

¹This research was supported by a Biomedical Sciences Support Grant to the University of Tennessee, Knoxville, and by grant number MH-24997 from the National Institute of Mental Health, USPHS. Reprints may be obtained from J. C. Malone, Department of Psychology, University of Tennessee, Knoxville, Tennessee 37916.

strength and persistence of the effect, though many authors have suggested that this variable may be important (*e.g.*, Bloomfield, 1966; Brethower and Reynolds, 1962). This variable is particularly relevant to Terrace's (1963) account, since contrast is presumed to depend upon unreinforced responding, which could be expected to depend in part on the similarity of stimuli used.

Farthing (1974) found that the magnitude of behavioral contrast was related to differences in the similarity of stimuli correlated with VI reinforcement and extinction. After nondifferential (VI) reinforcement for responding to randomized presentations of 12 line orientations (ranging from vertical to horizontal, in eight-degree steps), reinforcement was delivered for responding to only the first six orientations, while responding to the remainder was extinguished. Between Sessions 6 to 15, maximum responding typically occurred to the orientations more nearly adjacent to the S— set, rather than to those most distant from the S— set. Only after prolonged training (50 to 80 sessions) did peak response rates occur in those reinforced stimuli farthest removed from the S— set. Thus, during early training, contrast was greatest in those stimuli least discriminable from the nonreinforced set.

Similar results were reported by Catania and Gill (1964), who reinforced pigeons' responding according to a fixed-interval (FI) schedule when any one of the upper eight of a column of 16 small lamps was lit. These authors found that response rates were highest in the presence of the lamp associated with reinforcement that was adjacent to the S— set (*i.e.*, the eighth lamp from the top of the column).

Unlike Farthing, Catania and Gill found some evidence for a corresponding effect in the S+ set; response rates were lowest to the lamp adjacent to the S+ set (*i.e.*, the ninth lamp from the top of the column). Responding was slightly greater to lamps 10 and 11, but decreased in stimuli more remote from the S+ set. These differences in responding within the S+ and the S— sets were transient, but returned when the "boundary" separating reinforcement and extinction was changed or when a sheet of plastic obscured the lamp display, rendering the stimuli less discriminable. Similar results, appearing in group averaged data, were recently reported by Blough (1975),

who used wavelength of light as a stimulus continuum.

In the present experiments, an attempt was made to replicate the essential findings both of Farthing and of Catania and Gill. As in Farthing's study, line-orientation stimuli were used but only four, rather than 12 orientations appeared. Unlike Farthing's results, where near-zero responding prevailed in the S— set, clear effects similar to those reported by Catania and Gill appeared in both the S+ set and the S— set.

EXPERIMENT 1

In the first experiment, pigeons' responding was equally reinforced in the presence of four line orientations. Subsequently, responding was reinforced only in two adjacent orientation stimuli.

METHOD

Subjects

Four Silver King pigeons were reduced to 80% of their free-feeding weights and maintained there throughout the experiment. All four animals had been autoshaped to peck a green key approximately four months earlier; otherwise, all of them were experimentally naive.

Apparatus

The experimental chamber was a 27 by 25 by 35 cm aluminum and Plexiglas box with a 1.9 cm translucent key mounted on one wall. The center of the key was 24 cm from the floor of the chamber. Line-orientation stimuli were provided by a stimulus projector (Grason-Stadler Model A509-24) mounted directly behind the key; lines were 1.9 cm long and approximately 3 mm wide, as they appeared on the key. The experimental chamber was enclosed in a larger box (86 by 61 by 61 cm) composed of hollow 6.4-cm thick walls filled with soundproofing materials. Reinforcement (3-sec access to mixed grain) was provided by a food magazine; the 5 by 6.4 cm magazine aperture was located 8.9 cm below the key. The 6-W houselight and the key display were extinguished during reinforcement. The soundproofed box and a ventilation fan masked extraneous noises; scheduling and recording equipment was located in an adjoining room.

Procedure

After preliminary magazine and key training, all birds began the first condition. Each session consisted of presentations of four line-orientation stimuli: 90° (vertical), 60°, 30°, and 0° (horizontal). Stimulus presentations lasted 1 min and were arranged in a fixed sequence of 49 presentations, randomized, with the restrictions that each orientation stimulus preceded itself and each other orientation equally often and that the same stimulus appeared during no more than two consecutive presentations. Earlier work (Malone and Staddon, 1973) showed that response rates during a stimulus presentation are influenced by the immediately preceding presentation (local contrast). Arranging the sequence in this way precluded the possibility that overall differences in response levels during a session could be caused by this factor. To minimize time-in-session effects, each stimulus appeared equally often in each of the four blocks of 12 presentations. Ninety degrees (vertical) appeared 13 times per session, while each other orientation appeared 12 times.

The experiment consisted of two conditions:

(1) *VI All*: responding to all stimuli was reinforced according to a variable-interval (VI) 1-min schedule; choice of interreinforcement intervals was based on the progression suggested by Fleshler and Hoffman (1962).

(2) *VI 90°, 60°, / 30°, 0°*: responding was reinforced according to VI 1-min only in the presence of two orientation stimuli, 90° and 60°, or 30° and 0°. Birds assigned to each condition and the number of sessions of training are shown in Table 1.

RESULTS

Figure 1 shows response rates for each bird during the last five days of *VI All* and during two-day blocks of the entire period of differential reinforcement.

Table 1

Number of Sessions in Each Condition of Experiment I

<i>Bird</i>	<i>VI All</i>	<i>VI 90°, 60°</i>	<i>VI 30°, 0°</i>
81	18		22
82	19	20	
83	20		22
84	19		22

All four birds responded at approximately equal rates to the four orientation stimuli during *VI All* (left panel of each figure), though some variability appeared in the data of Bird 82. With the change to differential reinforcement, responding increased to orientations presented with reinforcement and decreased to nonreinforced stimuli (except Bird 82).

Clear and persistent effects similar to those reported by Catania and Gill (1964) appear in the data of Birds 81 and 83, represented as shaded areas. Thus, response rates were higher to 30° than to 0° and lower to 60° than to 90° throughout training. Birds 82 and 84 showed little differences in response rates within the S+ and the S- sets.

DISCUSSION

Two of the four birds showed effects similar to those reported by Catania and Gill (1964) when responding was reinforced in the presence of two adjacent line-orientation stimuli and extinguished during two orientations adjacent to them. These results are not, therefore, confined to their particular form of spatial discrimination nor to FI reinforcement schedules. Both positive and negative effects appeared; unlike their results (and those of Farthing, 1974), where the negative effects were weak or absent, these effects appeared more pronounced and more durable than were the positive effects. For both birds, the effects persisted, more or less, over the period of training used here.

EXPERIMENT II

Catania and Gill reported that their effects disappeared after two or three weeks of training, but could be recovered by rendering the discrimination more difficult by covering the stimulus display with a plastic plate. In the second experiment, the stimuli were rendered less discriminable by substituting orientations more closely spaced than those used in Experiment I.

METHOD

Subjects and Apparatus

Both were the same as in Experiment I.

Procedure

The presentation sequence of stimuli was that used in the first experiment, except that

Fig. 1. Responses per minute for individual animals during Experiment I. The left panel of each figure shows performance during the last five days of VI All. Right panels show response rates (in two-day blocks) during the entire period of differential reinforcement. Positive and negative effects appear as shaded areas. See text for details.

presentations of 75° were substituted for 90°, and 45° replaced 0°, leaving orientations of 75°, 60°, 45°, and 30°. Reinforcement was provided according to the VI schedule used in Experiment I for responding to all four stimuli. This was followed by discrimination training; *i.e.*, VI reinforcement for only two orientations (VI 75°, 60° / 45°, 30°). Orientations associated with reinforcement, as well as

number of sessions of equal reinforcement (VI All) and number of sessions of discrimination training appear in Table 2. For Bird 81, orientations nearer the horizontal were those presented with reinforcement, as was the case in the first experiment; for the other three birds, orientations presented with reinforcement were the “complement” of those formerly presented with reinforcement.

Table 2
Number of sessions in each condition of Experiment II.

Bird	VI All	VI 75°, 60°	VI 45°, 30°
81	29		44
82	28		42
83	27	40	
84	27	40	

RESULTS

Figures 2 and 3 show the performance of each bird during the last five days of VI All and during two-day blocks of the entire period of differential reinforcement.

After approximately 25 sessions of equal reinforcement during all stimuli, response rates appeared stable (though some changes in over-

Fig. 2. Responses per minute for Birds 81 and 83 during Experiment II. The left panel of each figure shows performance during the last five days of VI All. Right panels show response rates (in two-day blocks) during the entire period of differential reinforcement. Positive and negative effects appear as shaded areas. See text for details.

all level of responding were shown by Birds 82 and 84) and approximately equal to the four stimuli (left panels of Figures 2 and 3). With the change to reinforcement during only two stimuli, differential responding developed, but at a much slower rate than in Experiment I.

Bird 81 responded more rapidly to 45° than to 30° from the onset of differential reinforcement and continued to do this throughout the 44 days of training (Figure 2, shaded area). The magnitude of this positive effect appeared to be greater than the corresponding negative effect in Experiment I. A corresponding negative effect

was absent; in fact, responding was generally higher to 60° than to 75°.

Bird 83 showed little evidence of differential responding over the first 24 sessions of VI 75°, 60°. Response rates to 75°, 60°, and 30° then increased over the remaining sessions. Positive and negative effects then appeared (Figure 2, lower panel) and remained during the last 16 sessions. The strong negative effect (lower response rates to 45° than to 30°) remained undiminished; the positive effect (higher response rates to 60° than to 75°) was equally persistent but comparatively smaller.

Fig. 3. Responses per minute for Birds 84 and 82 during Experiment II. The left panel of each figure shows performance during the last five days of VI All. Right panels show response rates (in two-day blocks) during the entire period of differential reinforcement. Positive and negative effects appear as shaded areas. See text for details.

Differential responding was shown by Bird 84 by Sessions 10 to 12 (Figure 3, upper panel). A negative effect (lower response rates to 45° than to 30°) persisted through most of the 40 sessions of training; a corresponding positive effect (higher response rates to 60° than to 75°) was virtually absent, appearing only over a few of the last sessions.

Bird 82, which showed negligible effects in the first experiment, showed clear positive and negative effects and quite stable differential responding after the first eight or nine sessions of VI 45°, 30°. Responding was consistently higher to 45° than to 30° and lower

to 60° than to 75° throughout the remainder of the 42 training sessions. Both effects remained strong, as was the case with Bird 83.

DISCUSSION

In this experiment, both positive and negative effects, when present, were stronger than was the case in Experiment I. A positive effect was clear in the data of Birds 81, 82, and 83 and remained strong throughout training. A strong negative effect was apparent for Birds 82, 83, and 84 and it also persisted through training.

Any differences in the strength of these ef-

fects in the two experiments must be interpreted with some caution, of course. The discriminability of the stimuli was not the only factor involved; both the experience in Experiment I and the "reversal" of orientations presented with or without reinforcement could have affected performance during this experiment. One would assume, however, that experience in the first experiment would, if anything, have rendered the effects weaker and more transient, whereas the opposite occurred.

The reversal of the orientations presented with and without reinforcement could have contributed to the greater length of time required for differential responding to develop in this experiment and perhaps could have been responsible for the increased strength and persistence of the effects. In particular, this could account for the unexpectedly high response rates to 30° shown by Bird 83. However, this could apply only to the performance of Birds 83 and 84 (Experiment I: VI in 30°, 0°; Experiment II: VI in 75°, 60°) and Bird 82 (from VI in 90°, 60° to VI in 45°, 30°). Bird 81, which experienced no reversal (from VI in 30°, 0° to VI in 45°, 30°) showed strong and durable effects (though only positive) along with the others. Thus, it seems safe to suppose that the differences between the two experiments was a function of the discriminability of the stimuli used.

GENERAL DISCUSSION

The present procedures could be expected to produce several results. First, one could expect response rates to conform to the reinforcement contingencies in force, independent of particular stimuli within the S+ or the S- set. This would simply lead to higher response rates in both stimuli presented with reinforcement and lower rates in those presented in extinction. This occasionally occurred; it was the case in Experiment I for Birds 82 and 84 and in Experiment II for Bird 84 (applying to stimuli in the positive set).

A second (and perhaps more likely) outcome would be differences in response rates within the positive and negative sets, which would be interpretable in terms of stimulus generalization; *i.e.*, highest response rates in that member of the S+ set more distant from the S- set and lowest response rates in that

member of the S- set more distant from the S+ set. Clear differences of this kind appeared only for Bird 81 for stimuli in the negative set during Experiment II. Weak effects also appeared in the data of Bird 84 (Experiment I, positive and negative sets; Experiment II, positive set), but these differences were certainly not striking.

The third result possible would be the appearance of effects replicating the essential findings of Catania and Gill (1964) and of Farthing (1974). Positive effects, or greater response rates during that stimulus adjacent to the pair presented in extinction, appeared in Experiment I for Birds 81 and 83 and in Experiment II for Birds 81, 82, and 83. Negative effects, or lower response rates during that stimulus adjacent to the pair presented with reinforcement, appeared in Experiment I for Birds 81 and 83 and in Experiment II for Birds 82, 83, and 84. Effects, when present, persisted throughout the period of training used here.

Negative effects were not reported by Farthing, who obtained near-zero response rates in all stimulus values presented in extinction. A variety of differences in procedure could account for persistent S- responding found here; for example, the smaller number of stimuli used here (a total of four *versus* Farthing's 12) could be responsible. The effects in these experiments persisted through as many as 42 sessions, which was the maximum period of training in Experiment II. Farthing reported that his (positive) effects persisted over a comparable period, with peak response rates shifting to that stimulus furthest removed from the S- set during Sessions 40 to 80.

These results, like those of Catania and Gill and of Farthing, argue against an interpretation of discrimination formation in terms of stimulus generalization, such as that proposed by Spence (1937) or by Skinner (1938). Differences in response rates did not seem explainable in terms of the generalized effects of reinforcement and extinction (*cf.* Malone, 1974).

The occurrence of stimulus-specific contrast effects seems at first consistent with Terrace's (1963, 1966) account, but only as it may apply to positive effects. That is, one could argue that these effects depend on "emotionality" arising from nonreinforced responding to members of the S- set and that the degree of

emotion-produced enhancement of responding is greater when the discrimination is more difficult. Thus, response rates may be higher to stimuli adjacent to the nonreinforced stimuli. Similarly, the effect should be stronger in Experiment II, where the stimuli were more similar. However, this interpretation does not easily account for the persistence of the effects and can in no way account for the negative effects that occurred in both experiments.

Similar problems apply to the additivity theory of contrast proposed by Gamzu and Schwartz (1973). According to this account, positive contrast occurs when responding maintained by the reinforcement schedule (*i.e.*, the response-reinforcer relation) is augmented by responses controlled by the stimulus signalling reinforcement (*i.e.*, the stimulus-reinforcer relation). Rachlin (1973) and others have summarized evidence supporting this view; nonetheless there remain several aspects of contrast that pose difficulties for the additivity theory. For example, Reynolds (1963) and others have reported cases of negative contrast, which appears as decreased responding in one component of a multiple schedule as a function of an increase in reinforcement frequency in a second component. It may be argued in this case that responses controlled by the stimulus-reinforcer relation are "inhibited", but as Schwartz (1975) points out, this is not a very plausible argument. However, Schwartz goes on to defend the additivity theory and presents evidence that positive and negative contrast may be unrelated and may therefore depend upon different mechanisms.

The negative effects described here seem clearly to mirror the positive effects; if these effects do represent instances of contrast, it seems difficult to suppose that positive and negative contrast depend upon basically different mechanisms. In addition, these effects, as well as those of Blough (1975) and Farthing (1974), suggest a stimulus specificity that seems difficult to reconcile with additivity theory.

The account most in accord with these data is that suggested by Catania and Gill (1964) and by Farthing (1974), and which I have suggested (Malone and Staddon, 1973) may deal with other contrast data. Specifically, these effects may be viewed as analogous to that body of data that supports Békésy's (1967)

"neural unit" model for interactions appearing in a variety of sensory systems, both human and animal. While this model may have only heuristic value in interpreting contrast data (as Farthing suggests), Békésy's evidence and other supporting data (*e.g.*, Ratliff, 1965) seem to provide strong support for the usefulness of this model. It is perhaps more than coincidence that a very similar model was used by Pavlov (1927, Lectures IX and XI) to account for similar data. There is no reason to suppose that such a model may not be profitably applied to these and other data that otherwise seem very puzzling.

REFERENCES

- Békésy, G. V. *Sensory inhibition*. Princeton, N.J.: Princeton University Press, 1967.
- Bloomfield, T. M. Two types of behavioral contrast in discrimination learning. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 155-161.
- Blough, D. S. Steady state data and a quantitative model of operant generalization and discrimination. *Journal of Experimental Psychology: Animal Behavior Processes*, 1975, **104**, 3-21.
- Brethower, D. M. and Reynolds, G. S. A facilitative effect of punishment on unpunished behavior. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 191-199.
- Catania, A. C. and Gill, C. A. Inhibition and behavioral contrast. *Psychonomic Science*, 1964, **1**, 257-258.
- Farthing, G. W. Behavioral contrast with multiple positive and negative stimuli on a continuum. *Journal of the Experimental Analysis of Behavior*, 1974, **22**, 419-425.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 529-530.
- Gamzu, E. and Schwartz, B. The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 65-72.
- Hearst, E., Besley, S., and Farthing, G. W. Inhibition and the stimulus control of operant behavior. *Journal of the Experimental Analysis of Behavior*, 1970, **14**, 373-409.
- Malone, J. C. Jr. The effect of number of stimuli on the steady-state generalization gradient: A test of the summation hypothesis. *Journal of Experimental Psychology*, 1974, **102**, 729-732.
- Malone, J. C., Jr. and Staddon, J. E. R. Contrast effects in maintained generalization gradients. *Journal of the Experimental Analysis of Behavior*, 1973, **19**, 167-179.
- Pavlov, I. P. *Conditioned reflexes*. (Tr., G. V. Anrep.) New York: Dover, 1927.
- Rachlin, H. Contrast and matching. *Psychological Review*, 1973, **80**, 217-234.
- Ratliff, F. *Mach bands: quantitative studies on neural networks in the retina*. San Francisco: Holden-Day, 1965.

- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 57-71.
- Reynolds, G. S. Some limitations on behavioral contrast and induction during successive discrimination. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 131-139.
- Schwartz, B. Discriminative stimulus location as a determinant of positive and negative behavioral contrast in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1975, **23**, 167-176.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century, 1938.
- Spence, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychological Review*, 1937, **44**, 430-444.
- Terrace, H. S. Discrimination learning with and without errors. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 1-27.
- Terrace, H. S. Stimulus control. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 271-344.
- Terrace, H. S. Discrimination learning, the peak shift, and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 727-741.

Received 1 July 1974.

(Final Acceptance 23 June 1975.)