

## BEHAVIORAL AND DIMENSIONAL CONTRAST IN RATS

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Rats pressed a nose key for brain stimulation reinforcement presented on a fixed-interval schedule. Stimuli were drawn at random from a continuum of 12 white noise intensities in the range 62-95 decibels, spaced in 3 decibel steps. Experiment 1 varied the number of stimuli and the reinforcement contingencies associated with them. In Condition I (baseline) all stimuli signaled reinforcement; in Conditions II and III stimuli from one half of the continuum signaled reinforcement and those from the other half, extinction. However, in Condition II the 6 stimuli from the middle of the continuum were omitted. Experiment 2 held constant the number of stimuli and varied their spacing. In Condition I, each of 6 sounds signaled reinforcement. In Conditions II and II, three stimuli from one half of the continuum signaled reinforcement and three from the other half, extinction. However, in Condition II the stimuli were near the extremes of the continuum (Stimuli 1, 3, 4, 9, 10, 12). Condition III replaced Stimulus 3 with Stimulus 6 and Stimulus 10 with Stimulus 7. Behavioral contrast was seen in an increase over baseline in response rate to the stimuli associated with the constant schedule component when the variable component was changed to extinction. Dimensional contrast was seen in a further elevation of rate to intermediate positive stimulus values when stimuli were added to the border region between positive and negative values.

*Key words:* behavioral contrast, dimensional contrast, psychophysical tasks, auditory stimuli, intracranial stimulation, fixed-interval schedules of reinforcement, nose-key pressing, rats

In operant experiments contrast effects occur when response rate in a constant condition varies with the context of that condition. In the most common instance, rate during a constant component of a multiple schedule varies with reinforcement frequency in neighboring components. This phenomenon, known as behavioral contrast, takes many forms and has been the subject of a large number of studies. A second type of contrast is dimensional contrast. It occurs when response rate during a constant component of a multiple schedule depends on which of several stimuli signals that component.

Catania and Gill's 1964 study was the first to distinguish between these effects. Pigeons pecked a key for food reinforcement delivered on a multiple fixed-interval extinction schedule. A vertical array of 16 lights, located to the side of the key, signaled the components. One experiment demonstrated a form of behavioral

contrast; a single light in the array (S+) signaled reinforcement and another (S-), extinction. Response rate during S+ was higher following an S- component than following an S+ component. A second experiment demonstrated an effect like dimensional contrast: any light in one half of the array signaled reinforcement; any light in the other half signaled extinction. Now response rate depended on the spatial location of the signaling lights. Rate was highest when the S+ was physically adjacent to the set signaling extinction. It declined as the positive stimulus moved away from the S+/S- border.

Research by D. Blough (1975, in press) has explored dimensional contrast more fully. His experiments also used pigeons; stimuli were lights of varying wavelengths projected onto the pecking key. A typical experiment used a series of wavelengths scaled for discriminability and spaced perceptually closely. The light in the middle of the series (S-) was associated with a lower probability of reinforcement than the remaining stimuli (S+). Dimensional contrast effects appeared as "shoulders" in the gradient relating response rate to stimulus wavelength. Rate was lowest for the S-; it

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grew and then declined as the S+ moved from the center to either edge of the continuum. These findings are similar to those of Catania and Gill (1964) in that rate in S+ depends on its perceptual proximity to the S-.

To account for dimensional contrast, Blough proposed a model conceptually similar to that of Rescorla and Wagner (1972). A unique feature of the Blough model is a generalization parameter that describes interactions among stimuli on a continuum. Thus, the associative strength of a stimulus depends partly on the associative strength of similar stimuli. Positive stimuli adjacent to an S- have a relatively low associative strength because of the negative influence of neighboring S- values. However, reinforcement in the presence of such a stimulus contributes a relatively high amount of associative strength to similar stimuli and strengthens the response to these neighbors more than it does to more distant values.

An important prediction of the Blough model concerns the effect of stimulus spacing on dimensional contrast. If stimuli are very dissimilar, the generalization factor will be low and the contrast effect diminished. Data reported by Essock and Blough (1977) support this prediction. Further, for dimensional contrast to occur, the continuum must include S+ values that are perceptually close to their S- neighbors. An important test of this aspect of the model was an omitted stimulus condition described by Blough (in press). This study showed a marked diminution in the contrast effect when stimuli close to the S+/S- border were omitted from the continuum.

Accounts of behavioral contrast are as varied as are the manifestations of the effect itself. One of these accounts, additivity theory (Schwartz & Gamzu, 1977), has received a good deal of recent experimental support (e.g., Hearst & Gormley, 1976; Keller, 1974; Schwartz, 1975). This theory proposes that positive contrast occurs when responses elicited by a stimulus-reinforcer association are added to those maintained by response-reinforcer contingencies. An important prediction, then, is that contrast will be restricted to situations in which the stimulus-reinforcer contingency elicits the same response as that maintained by the operant contingency. Typical pigeon studies in which a stimulus is projected on the response key and food is the reinforcer meet these conditions, and the studies cited above

show stronger positive contrast in such situations. Other experiments, however, have shown behavioral contrast in situations that do not conform to the requirements of additivity theory. For example, Gutman, Sutterer, and Brush (1975) showed positive contrast effects in rats pressing levers in a situation where the stimulus light or sound was spatially remote from the manipulandum. A recent paper by Schwartz (1978) suggests that additivity theory accounts best for local positive contrast, that is, for rate enhancement seen in the early, relative to the later, portion of a single multiple-schedule component. Hinson and Staddon (1978) proposed that behavioral competition may also contribute to the contrast effect; their hypothesis suggests that the introduction of an extinction component in a multiple schedule makes room for responses that otherwise compete with the measured response.

Blough's model of dimensional contrast appears to have no features in common with the various accounts of behavioral contrast, and it is likely that different processes account for these phenomena. The present study examined both behavioral and dimensional contrast within the framework of a single experiment. Its principal goal was to distinguish among the operations that produce the two effects. A secondary purpose was to extend studies of both types of contrast to a novel experimental situation. By avoiding spatial contiguity between the manipulandum and the discriminative stimulus, this situation was designed to minimize the role of responses elicited by a stimulus-reinforcer contingency. Rats pressed a continuously illuminated key for brain stimulation reinforcement (ESB). A series of white noise intensities, spaced in close perceptual steps and delivered through a loudspeaker at the opposite end of the chamber, served as stimuli. The two halves of the sound continuum signaled different components of a multiple schedule. Behavioral contrast was assessed by examining response rate during an unchanged component over changes in the variable-component schedule. Dimensional contrast was assessed by comparing conditions that included stimuli near the S+/S- border with ones that omitted such stimuli.

## EXPERIMENT 1

The first experiment compared two multiple-schedule discrimination procedures with

a baseline condition. During baseline responding was reinforced equally in the presence of 12 sound intensities. During discrimination stimuli from one half of the continuum signaled reinforcement; stimuli from the other half signaled extinction. The first discrimination condition used only the three sounds from each extreme of the continuum. The condition might favor behavioral contrast, but should not produce dimensional contrast because there were no stimuli near the S+/S- border. The second discrimination procedure added 6 stimuli to the border region. This condition should favor dimensional contrast superimposed on any behavioral contrast seen under the previous condition.

#### METHOD

##### *Subjects*

Four male albino rats, less than one year of age, served. They were from the CD strain produced at the Charles River Laboratories. Before the experiment each was implanted unilaterally with a bipolar electrode (Plastic Products Co., Type 303) aimed at the lateral hypothalamus. The effectiveness of this placement was evaluated several days later through operant conditioning in a separate apparatus. Placements were deemed effective if a nose-poke response was maintained at a steady rate by some level of ESB, and only those rats with effective placements served as subjects. Rats R4, R23, and R44 were naive. Rat R1 had had extensive experience on discrimination tasks using the same sound stimuli. They were fed approximately 20 gm of laboratory rat chow daily.

##### *Apparatus*

The subject chamber was a box, 33 cm wide by 26 cm deep by 48.5 cm high, constructed of clear plastic and aluminum. A pigeon key was mounted behind a 2.5-cm opening in the center of the aluminum front panel, 6 cm above the grid floor of the chamber. The key was transilluminated by a 32-V (GE 1841) lamp whose light first passed through a red filter. A sound-attenuating enclosure housed the subject chamber. A second 32-V lamp, dimmed by added resistance, was mounted on a side wall of the housing and served as the houselight. A loudspeaker delivered the stimulus sounds; it was mounted near the center of the enclosure wall opposite the chamber's front panel, and

its center was 55 cm above the grid floor of the chamber. Thus, if the rat was facing the response key, stimuli came from above and behind him.

Mounted on the ceiling of the sound-attenuating enclosure was a mercury swivel commutator (Berkley & Kling, 1967) that allowed the rat to move freely while connected to the source of brain stimulation. This source, located outside the enclosure, delivered 60-Hz controlled-current sinewave stimulation. An oscilloscope continuously monitored its amplitude.

A Grason Stadler Model 901B Noise Generator was the source of the white noise stimuli. Mallory T-pads attenuated the sound and permitted the delivery of 12 independently adjustable intensities. The stimuli were calibrated with a General Radio Model 1551B Sound Lever Meter, its microphone probe placed approximately 4 cm from the response key. Stimulus 1 had an intensity of 62 dB, and Stimulus 12, 95 dB SPL (A scale); the remaining sounds were spaced equally at 3 dB steps within this range.

Electromechanical equipment programmed experimental sessions. Responses were recorded on counters and monitored by a cumulative recorder.

##### *Procedure*

For the naive rats training began when a minimum of one week had elapsed following surgery. The rats learned to press the key with their noses through conventional shaping procedures, and the response was then maintained by a fixed interval (FI) 1-sec schedule while the ESB current was adjusted. The amperage associated with the most stable responding was determined for each rat, and it was maintained at that value throughout the experiment. These values ranged from 50 to 200 microamperes; reinforcement duration was constant at 400 msec. Subsequent training sessions introduced FI schedules that gradually increased in duration until stable responding at FI 30-sec was achieved. Experimental sessions then began.

The sound stimuli were present during initial shaping and throughout the experiment. Within a session they occurred in a sequence of trials whose order was determined by a modified random-block design. A single block included 12 presentations, one of each sound

level during the 12-stimulus conditions and two of each sound level during the 6-stimulus condition. A program consisted of 12 such blocks. Within each block the order of stimuli was quasi-random with the restriction that, over the entire program, each value was preceded by a value in the high half of the continuum as often as it was preceded by a value in the low half.

A session consisted of 432 trials, each signaled by one of 12 stimulus sounds presented according to the program described above; that is, each session consisted of 3 cycles of the 144-stimulus program. The keylight and house-light were on continuously during the session. A trial consisted of a single stimulus presentation, which lasted for a minimum of 30 sec. For S+ trials reinforcement was set up at the end of the initial 30-sec period; it was available for 13 sec. Reinforcement or the end of the 13-sec hold, whichever came first, advanced the program to the next trial. For S- trials no reinforcement was set up, and trials ended with the termination of a 4-sec hold added to the trial period. In the case of R1 no response contingencies were in effect during S-; for the other rats, however, responses during the 4-sec hold reset the timer programming that interval. Responses were recorded only during the first 30 sec of each trial, so that differing S+ and S- trial durations did not affect the data.

A minimum of 12 warm-up trials preceded each regular session. The regular session began at a different point in the program each day. With a few exceptions, sessions took place daily and lasted approximately 3.5 hours.

The experiment consisted of three conditions. Condition I, a baseline, included all 12 sound levels, with the same FI 30-sec reinforcement schedule in effect for each value. Condition II was a discrimination procedure. The S+ values included the three stimuli at one extreme of the continuum; S- intensities were the three at the opposite extreme. Condition III was also a discrimination procedure, but it included 12 sound levels, 6 S+ and 6 S- values. Table 1 summarizes this information and shows how the stimuli were assigned to conditions as well as the order of conditions and the number of sessions at each. Rat R1 was trained in each condition until the data appeared stable; this qualitative-stability criterion took into account response

rates for all stimuli and permitted a change in conditions when there was no systematic rate change over three days. The other three rats received 4 to 8 sessions at each condition (Table 1). I changed to that strategy because the electrode preparation had a limited life, and it seemed preferable to allow time for replications rather than to await stability. Figures 1 and 2 indicate the extent of session-to-session variability.

Counters recorded responses associated with each stimulus. Totals included all responses that occurred during the initial 30 sec of each trial and were accumulated across each session. A cumulative recorder monitored responding within a session; if records revealed pausing that lasted 5 min or more, the data were not used and the session was repeated. Sessions omitted for this reason are indicated by missing points in Figures 1 and 2; the cause in most cases was a failure in the brain-stimulating equipment.

## RESULTS

All rats learned the response quickly, and the gradual increase in the FI requirement maintained steady responding. Stable FI 30-sec performance was achieved after several extended sessions. Cumulative records showed the break-and-run pattern typical of performance on short FI schedules; this pattern persisted through the entire experiment. Discriminations were quickly acquired; that is, rates in S- dropped markedly during the first discrimination session.

Figures 1 and 2 illustrate performance over sessions at two stimulus values. The unfilled circles represent a stimulus from the extreme end of the S+ half of the continuum (Stimulus 1 or 12); the filled circles represent an intermediate S+ value (Stimulus 3 or 10), whose associated intensity was closer to the S+/S- border.

Behavioral contrast can be seen in a comparison between Conditions I and II; Condition II should show an elevation of S+ response rates over Condition I or baseline rates. Figure 1 shows a marked contrast effect upon the initial introduction of Condition II (compare the first and second panels). A decrease in rate on return to baseline from Condition II is also marked for R23 (compare the fourth and fifth panels). For R4 and R44 return to

Table 1  
Procedure for Experiments 1 and 2

Rat	Condition*	Number of sessions	Stimuli	
			S+	S-
EXPERIMENT 1				
4	I (1, 5)	5	1-12	—
	II (2, 4)	5	10-12	1-3
	III (3)	8	7-12	1-6
23	I (1, 5)	5	1-12	—
	II (2, 4)	5	10-12	1-3
	III (3)	8	7-12	1-6
44	I (1)	6	1-12	—
	I (5)	5	1-12	—
	II (2)	6	1-3	10-12
	II (4)	5	1-3	10-12
	III (3)	8	1-6	7-12
1	I (4)	6	1-12	—
	II (2)	9	10-12	1-3
	III (1)	6	7-12	1-6
	III (3)	7	7-12	1-6
EXPERIMENT 2				
23	I (1, 5)	5	1, 3, 4, 9, 10, 12	—
	II (2, 4)	5	9, 10, 12	1, 3, 4
	III (3)	5	7, 9, 12	1, 4, 6
43	I (1)	5	1, 3, 4, 9, 10, 12	—
	I (6)	5	1, 4, 6, 7, 9, 12	—
	II (2)	6	1, 3, 4	9, 10, 12
	II (4)	5	1, 3, 4	9, 10, 12
	III (3, 5)	5	1, 4, 6	7, 9, 12
44	I (1)	5	1, 3, 4, 9, 10, 12	—
	I (6)	4	1, 4, 6, 7, 9, 12	—
	II (2, 4)	5	1, 3, 4	9, 10, 12
	III (3, 5)	5	1, 4, 6	7, 9, 12

\*Numbers in parentheses indicate position in sequence of conditions.

baseline brought about a small increase in rate during initial sessions, although final baseline levels were slightly lower than they were in the preceding condition. Rat R1 was exposed to the experimental conditions in a different order and did not receive an initial baseline procedure. Thus, this particular comparison is more difficult to make. However, during the final baseline condition (Figure 2, fourth panel), rates dropped to a level well below those previously shown in Condition II (second panel).

Figure 3 shows response rate to all 12 stimulus values averaged over most sessions for each condition. For R1 these values are based on the final 5 sessions for each condition; for the other 3 rats the means are based on the final 3 sessions for Conditions I and II and the final 6 sessions for Condition III. Since each session included a minimum of 36 trials at each stimulus, the relatively small number of sessions

reflects a large number of trials. Closed symbols describe the first, and open symbols, the second presentation of a condition. The variability associated with these points is illustrated in the individual-session data shown in Figures 1 and 2.

The behavioral contrast effect is summarized in Figure 3. Mean rate during Condition II (short dashes) was higher than it was during baseline (solid line) for all subjects and all S+ values. The elevation reflected by these means was seen during initial exposure and on replication of these conditions. There was no systematic difference among the three S+ values in the extent to which they revealed this contrast effect.

Dimensional contrast should be seen first in the shape of the function-summarizing discrimination performance in Condition III. The long dashes connecting the squares in Figure 3 describe these functions. For all sub-

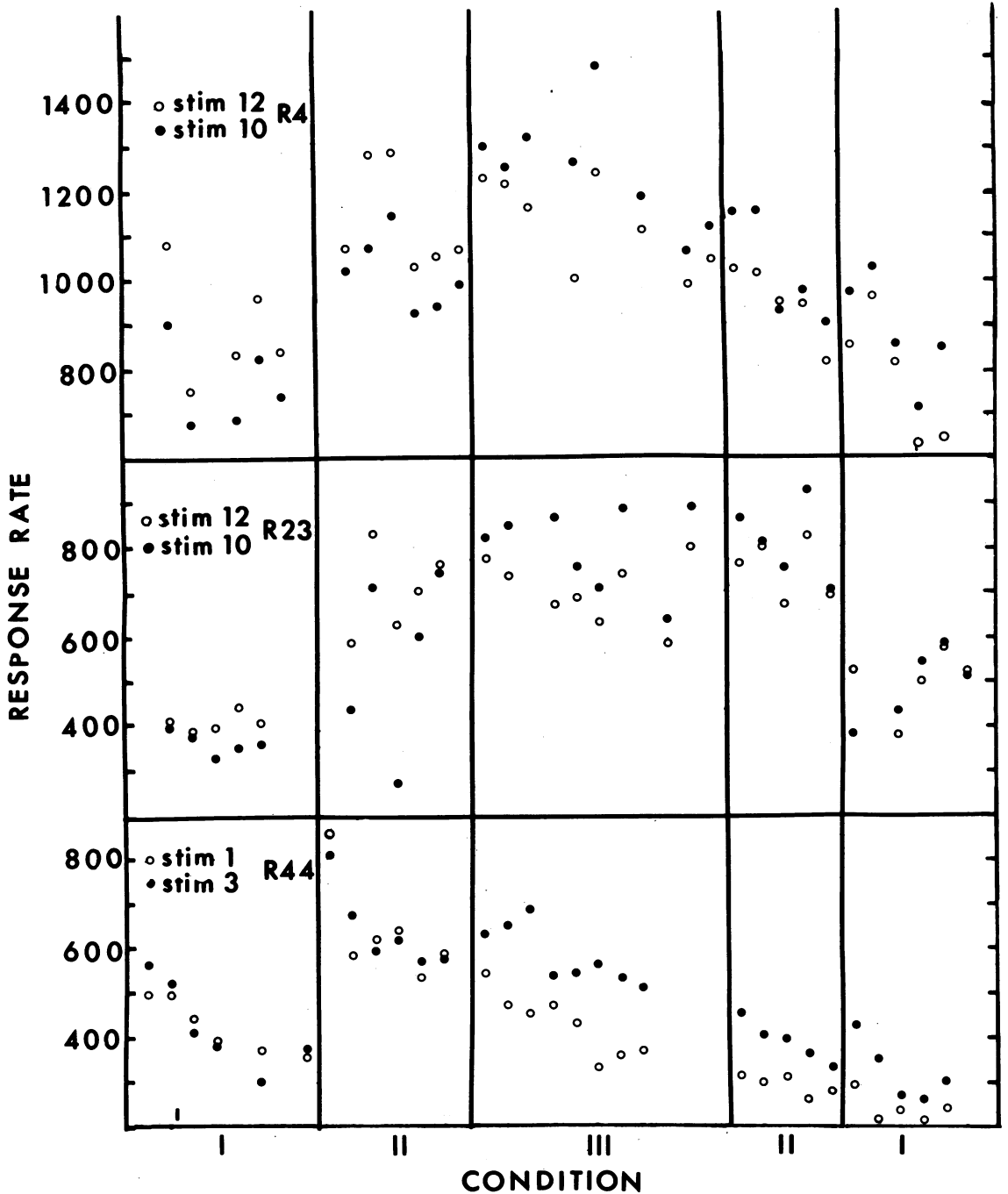


Fig. 1. Response rates during each session in Experiment I for two stimulus values. Stimulus 12 (R4, R23) or Stimulus 1 (R44) was at the outside extreme of the S+ continuum. Stimulus 10 (R4, R23) or Stimulus 3 (R44) was an intermediate S+ value. Data are shown for the experimental conditions in the order in which they occurred. For Conditions I and III session means are based on 36 presentations of a given stimulus; for Condition II the basis was 72 presentations. Ordinate values indicate responses per 18 min.

jects rates increased from a low value at the extreme S- intensities to a peak at intermediate S+ values. At extreme S+ values rate dropped off somewhat. The decrease in rate toward the inside of this peak may be attributed to poor discriminability; that is, these

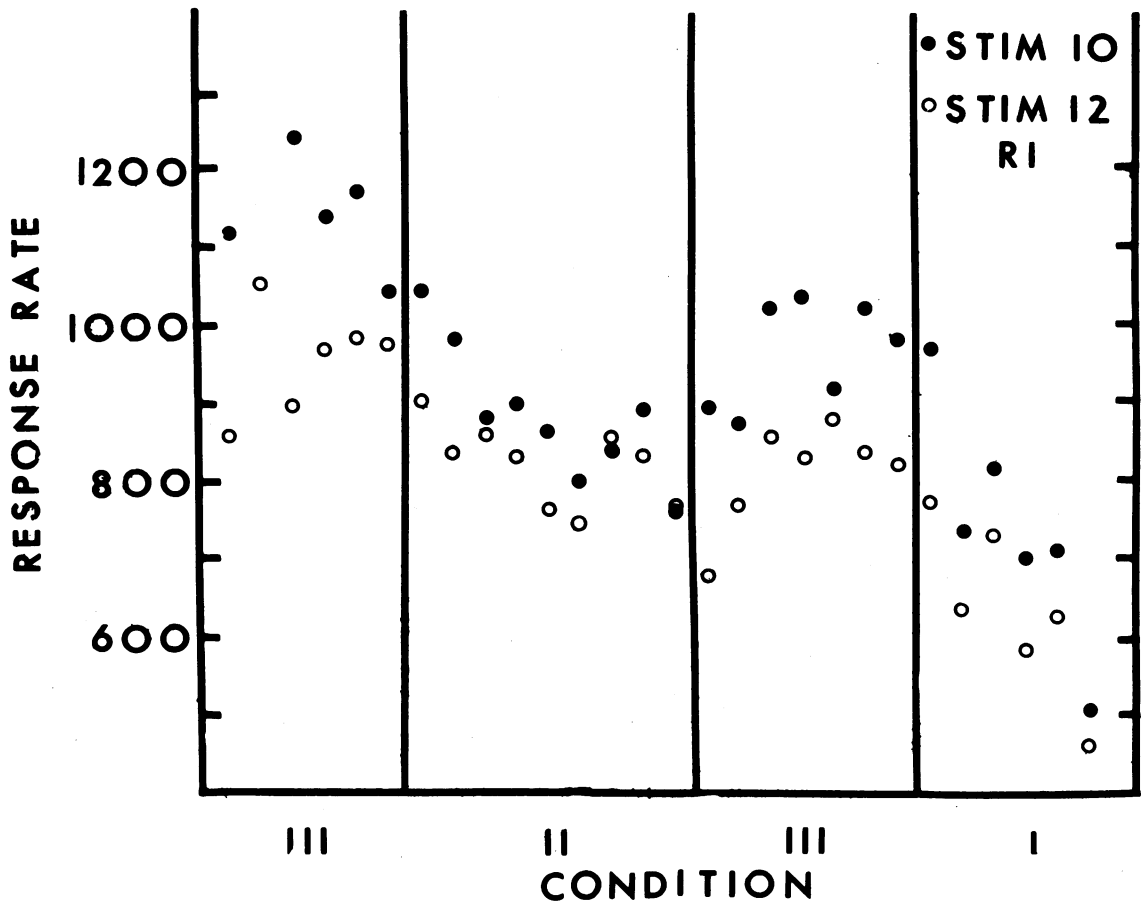


Fig. 2. Data shown as in Fig. 1 for an additional subject (R1), who was exposed to the experimental conditions in a different sequence.

sounds were similar to those associated with nonreinforcement. The fact that rate decreased toward the extreme of the S+ continuum may reflect dimensional contrast.

Comparison between Conditions II and III distinguishes between behavioral and dimensional contrast and replicates D. Blough's (in press) omitted stimulus experiment. Adding stimulus values to the center of the continuum should bring about or enhance dimensional contrast, which would be seen mainly as an enhancement in rate to intermediate S+ values, relative to rate to values toward the outside extreme of the S+ continuum. Subject R1 (Figure 2) shows this effect most clearly in the separation between response rates to intermediate and extreme S+ values that is unique to Condition III; the separation is marked by an increase in rate to the intermediate stimulus. For the subjects shown in Figure 1, the separation also occurred when Condition III

was introduced. While the absolute enhancement of responding to the intermediate sound level is less clearcut, response-rate difference for the two stimuli is in the appropriate direction for dimensional contrast. On return to Condition II, this separation was maintained in most instances, although overall rate decreased for two of the three subjects. For those two rats separation persisted on return to baseline.

The means shown in Figure 3 summarize the comparison between Conditions II and III. All four subjects in Condition III showed a clear drop in rate as the outside of the S+ continuum was approached; such a decline was small or nonexistent in the means across replications of Condition II. With two exceptions mean S+ rates in Conditions III were higher than they were in Condition II; this elevation was greater for the intermediate than for the outside stimuli.

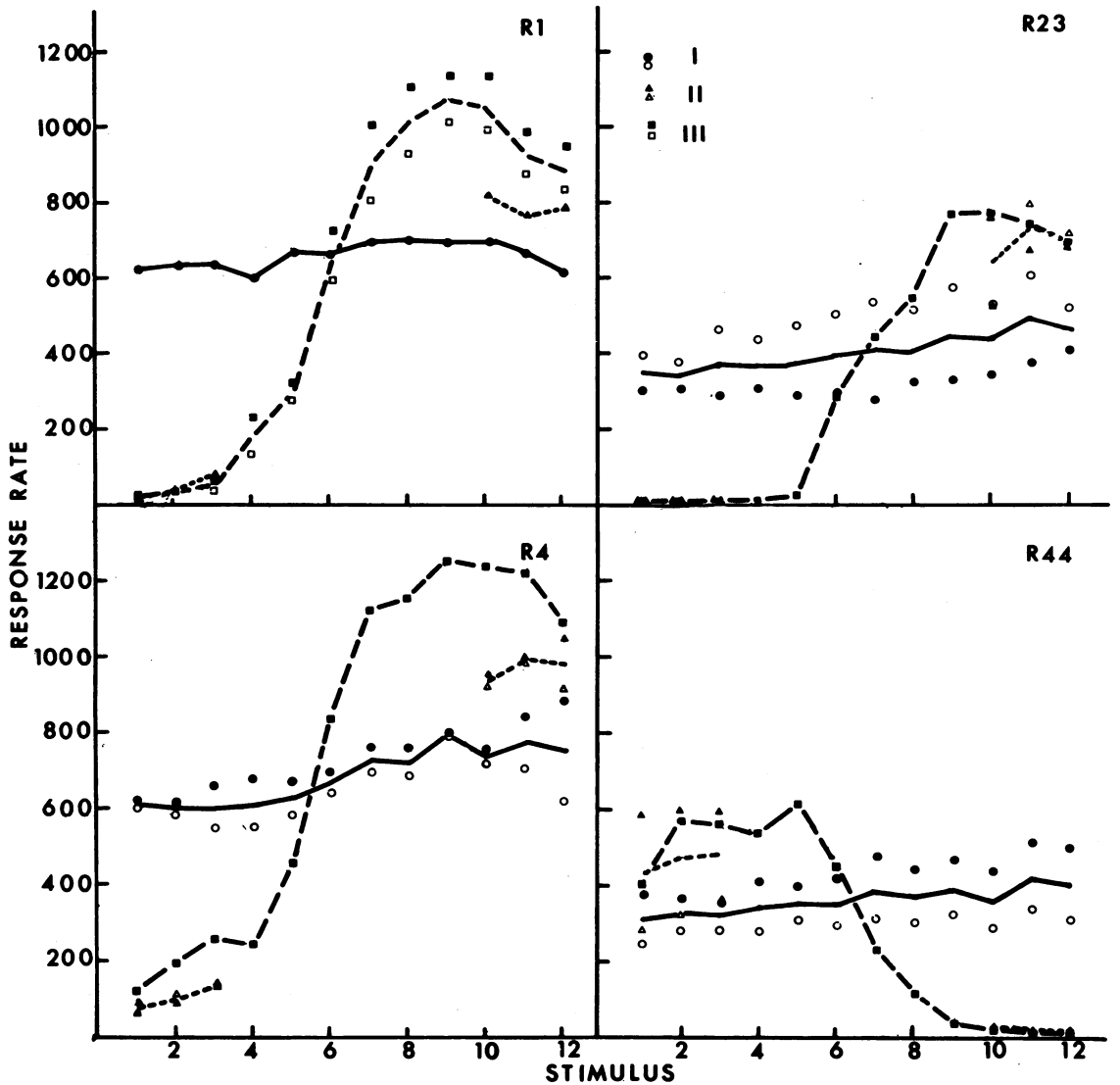


Fig. 3. Response rate as a function of stimulus intensity for four subjects in Experiment 1. Points are means across sessions as described in the text. Closed symbols describe the initial exposure to a given condition and open symbols, its replication. Stimulus values refer to a series of white noise intensities, where Stimulus 1 was the lowest intensity and the remaining values indicate 3 dB increments in sound level. Ordinate figures indicate responses per 18 min.

## EXPERIMENT 2

Experiment 1 showed dimensional contrast in a design similar to that of D. Blough's (in press) omitted-stimulus experiment. The introduction of stimulus values around the S+/S- border enhanced responding at intermediate relative to extreme S+ values; conversely, the omission of such values diminished the contrast shoulder. This finding is consistent with Blough's theory, which requires the

presence of stimuli similar to both S- and S+ neighbors to bring about this contrast effect. However, in Experiment 1 Conditions II and III also differed in the number of stimuli present during a session. It should also be possible to obtain dimensional contrast by changing the spacing in a continuum containing a constant number of stimuli. The effect should be seen when the series contains stimuli similar to their S- and S+ neighbors, but it should disappear if such stimuli are moved toward the



outside extremes of the continuum. Experiment 2 tested this prediction by using a constant number of stimuli and varying their spacing in a design otherwise similar to that of Experiment 1.

#### METHOD

##### *Subjects*

Two of the subjects were rats used in Experiment 1, R23 and R44. A third, naive male rat, R43, was also used. He, too, was less than one year of age. Electrode placement was the same as in Experiment 1.

##### *Apparatus*

The apparatus was the same as that used in Experiment 1.

##### *Procedure*

Except for the stimulus sets, the procedure was like that of Experiment 1. In Experiment 2, however, only 8 of the original set of 12 intensities were used. Condition II used stimuli 1, 3, 4, 9, 10, and 12. Condition III used stimuli 1, 4, 6, 7, 9, and 12. Thus the set used in Condition III differed only in that stimuli near the S+/S- border replaced intensities closer to the outer extremes of the range. Table 1 shows how the stimulus sets were associated with conditions as well as the order of presentation and the number of sessions for each condition. As in Experiment 1, conditions changed after a fixed number of sessions.

For R23, S+ values were from the more intense half of the stimulus continuum; for R43 and R44 they were from the less intense half. The reset contingency was in effect during S- for all rats; that is, S- did not terminate until at least 4 sec elapsed without a response. All other response contingencies were as in Experiment 1.

#### RESULTS

The rats in this experiment also showed characteristic FI response patterns after initial training sessions. Figure 4 shows, for each rat, response rate over sessions to stimuli in the center and at the outside extreme of the S+ continuum. As in Experiment 1, a comparison between Conditions I and II assesses the behavioral contrast effect. When the initial discrimination (Condition II, second panel) was introduced, there was a clear elevation in response rate for all subjects; however, it did not

persist for R44. Final baseline rate, compared to the replication of Condition II, dropped markedly for R43, somewhat for R23, but remained about the same for R44 (compare sixth with fourth panel).

Condition III used a stimulus arrangement expected to produce dimensional contrast. On its introduction (Figure 4, third panel), response rate to the intermediate S+ increased for all three subjects; for R23 rate to the outside stimulus also increased. This finding was replicated (fifth panel) for R43 and R44, although the effect was transient for R43. The rate separation expected in dimensional contrast was not restricted to Condition III, however; rate was higher to the intermediate than to the outside S+ in almost all conditions.

Table 2 shows mean response rates over the last three sessions for each stimulus and each condition. The points in Figure 4 indicate the variability associated with these means.

Figure 5 summarizes the comparisons among conditions. The left column compares rates associated with the intermediate S+ (Stimulus 4 or 9) across the three conditions. Behavioral contrast would be seen as an increased rate in Condition II compared to Condition I. As the left column of Figure 5 indicates, such an effect occurred for the intermediate S+ for all three rats. Table 2 shows that behavioral contrast occurred in almost every case for the other two S+ values as well. Dimensional contrast would be seen as an increase in rate in the intermediate compared to the outside S+. The right column of Figure 5 shows a measure of this effect. While rate for the intermediate S+ was relatively high in both Conditions II and III, this difference was greater in Condition III than in Condition II. The left side of Figure 5 shows that absolute rate associated with the intermediate S+ tended to be higher in Condition III than it was in Condition II, and this finding is also consistent with dimensional contrast; however, it was true for only two of the three rats.

#### GENERAL DISCUSSION

These two experiments demonstrated the occurrence of both behavioral and dimensional contrast in rats working for electrical stimulation of the brain. Further, the results showed that the two effects resulted from different operations. Behavioral contrast was seen as an

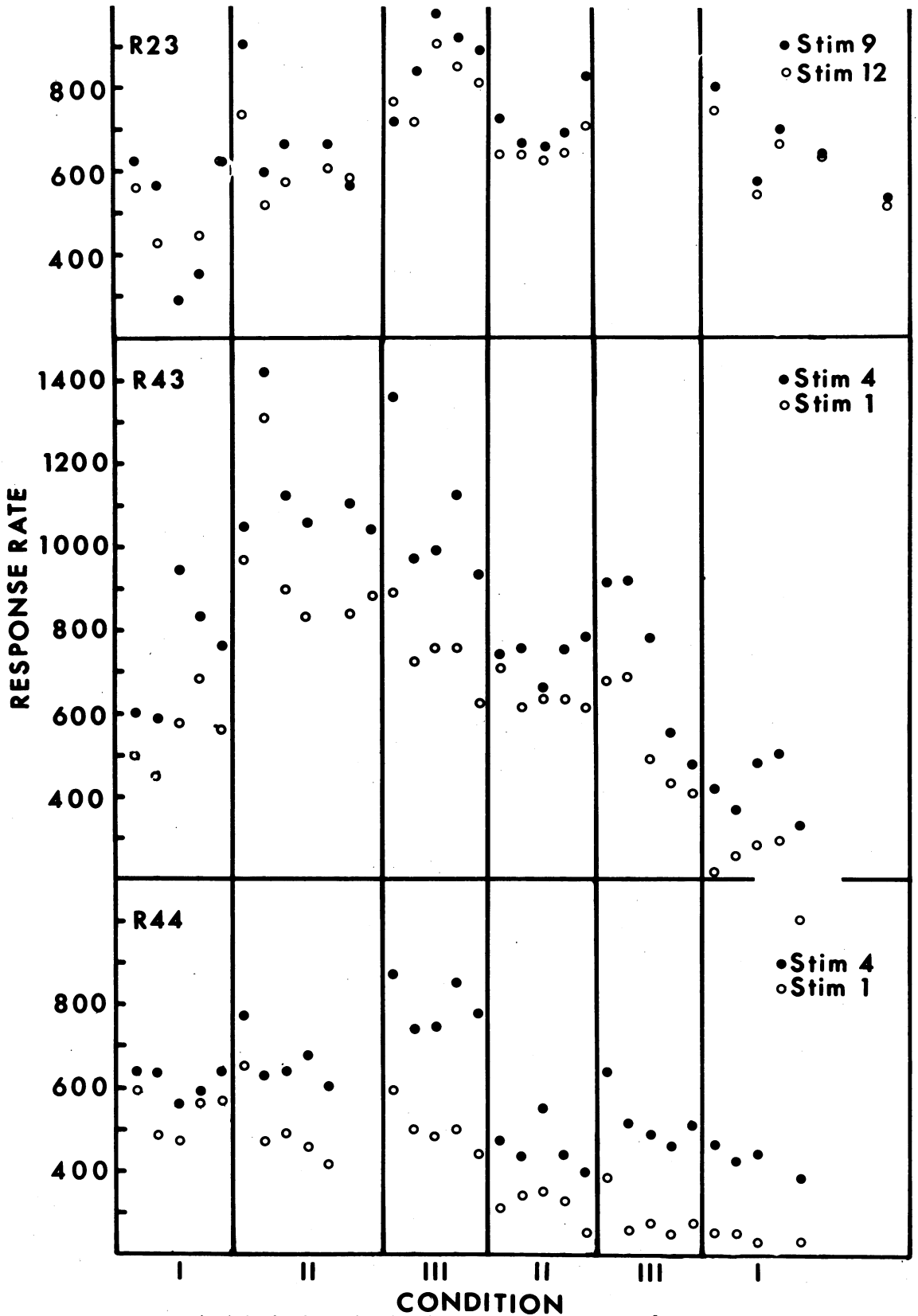


Fig. 4. Session by session data for Experiment 2, plotted as in Fig. 1.

Table 2

Rate of response (responses per 18 min) averaged over the final 3 sessions for each stimulus and condition in Experiment 2.

Rat	Condition	Stimulus							
		1	3	4	6	7	9	10	12
23	I	452	512	621			842	881	896
	II	6	6	22			1264	1246	1171
	III	10		108	602	1019	1857		1715
	II	10	12	49			1453	1467	1334
	I	753	793	810			1251	1226	1218
43	I	606	730	813			1025	943	927
	II	867	1109	1072			16	16	10
	III	709		1020	750	302	28		4
	II	625	787	732			5	3	4
	III	440		601	459	142	17		7
44	I	226		435	429	355	372		386
	I	537	612	594			652	581	639
	II	453	616	642			37	22	11
	III	475		796	640	427	51		19
	II	310	441	459			19	8	4
	III	268		487	512	254	42		24
	I	228		416	498	462	439		494

elevation in response rate during a constant component of a multiple schedule when an extinction condition was introduced. This effect occurred in the individual data for all rats under the conditions of both experiments. Dimensional contrast was seen as an interaction between response rate and stimulus position; response rate to an intermediate S+ was relatively enhanced when the stimulus continuum included values adjacent to the S+/S- border. This interaction, which appeared as a "shoulder" or peak in the S+ continuum, occurred in the data for all subjects under the conditions of both experiments.

In many of the cases noted above, the effects were small, and this fact may have resulted from certain features of the design. For example, contrast effects were generally larger on initial introduction of the appropriate condition; they did not always replicate well.<sup>1</sup> Perhaps the small number of sessions conducted at each condition did not allow contrast effects seen in previous conditions to dissipate.

<sup>1</sup>The return to baseline following positive contrast is sometimes termed "negative contrast" (Schwartz & Gamzu, 1977). Thus, failure to replicate the baseline effect can be interpreted as an absence of negative contrast rather than, for example, hysteresis. The present discussion instead refers to an "intraschedule" definition of contrast (McSweeney & Norman, 1979), which would require a return to baseline as a complete demonstration of the positive contrast effect.

The FI schedule used here could also have detracted from the size of the effects. For some subjects the final portions of the study suggest a declining response rate overall. This change could have resulted from an improving temporal discrimination. Further, although D. Blough's (1975, in press) studies of dimensional contrast used FI schedules, most studies of behavioral contrast have used variable-interval reinforcement. In such cases, reinforcement can occur while a schedule component is in progress, and it is possible that the reinforcing event adds to the rate increase. The present study used FI schedules in order to avoid the superposition of schedule on sound intensity cues. Innis (1978) has also shown behavioral contrast with FI schedules.

It is unlikely that additivity theory (Schwartz & Gamzu, 1977) can account for the behavioral contrast effects seen here. The illumination of the response key was unchanged during the experimental sessions and thus could not have become an eliciting stimulus by virtue of association with the reinforcer. There is no reason to expect that sounds originating from another portion of the chamber would elicit a response to the key. However, the specific effects of temporal association between sound and ESB are unknown, and the possibility remains that this contingency may somehow have facilitated the key-press response. My results, however, are consistent with those of

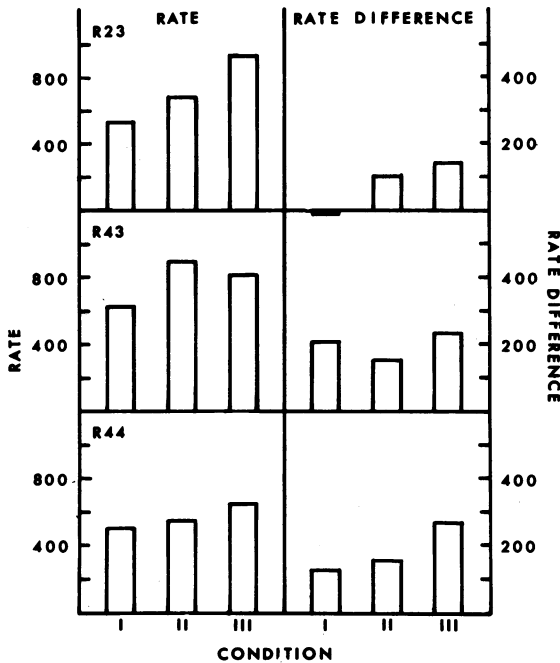


Fig. 5. Comparisons among conditions in terms of rate (left column) and rate difference (right column) based on mean data from Experiment 2. Values are the means of the last three sessions, averaged over replications. The rate data (left ordinate) refer to responses per 18 min in the intermediate S+, that is, Stimulus 9 (R23) or Stimulus 4 (R43, 44). The rate differences (right ordinate) refer to the rate during the intermediate S+ minus the rate during the outside extreme S+ value.

others (Beninger & Kendall, 1975; Gutman et al., 1978), who have used situations that should not elicit responding to show behavioral contrast in rats.

Hinson and Staddon's (1978) response-competition hypothesis does not require specific stimulus-response-reinforcer relations for its application. This hypothesis suggests that other responses compete with the measured response even when reinforcement is available. When periods of extinction are introduced, the competing responses are more likely to occur during those intervals and thus are less likely to interfere with the measured behavior. Hinson and Staddon's experimental basis was a study that showed more contrast when an attractive alternative response was available than when it was not. The present experiments did not test this hypothesis directly. However, it is possible that behavioral variability is greater in non-deprived subjects who are receiving brain stimulation; thus, subjects such as ours may engage more frequently in com-

peting responses during an experimental session.

The present data showed dimensional contrast using a technique like D. Blough's (in press) omitted-stimulus operation as well as with a more rigorous procedure that held the total number of stimuli constant. In the latter case (Experiment 2) the contrast effects were less marked, and this finding is consistent with Blough's theory, which emphasizes the role of interactions among stimuli on a continuum. Fewer and more widely spaced stimuli favor less such interaction than would occur under the conditions of Experiment 1.

The dimensional contrast shown in Blough's research was more complex than the effect seen here. Not only was there usually a shoulder or peak in the S+ continuum, there also was a trough adjacent to the S-. The present conditions did not favor such troughs, since the prevailing extinction conditions reduced S- responding to a minimum with a resulting floor effect. Blough's design raised this floor by occasional reinforcement in S-.

An experiment by Farthing (1974) yielded data similar to those seen in Conditions I and III of Experiment 1. Farthing used pigeons and a line tilt stimulus continuum which also was divided in half. During a baseline condition all stimuli were associated with equal variable-interval schedules. Then a discrimination condition was arranged in which half of the continuum signaled extinction. As in the present Experiment 1, rate in S+ varied with a peak appearing near the middle of the continuum. Further, for all S+ values rate was higher during the discrimination than during baseline. Thus, both dimensional and behavioral contrast occurred. Farthing interpreted the data in terms of interacting effects of behavioral contrast and stimulus similarity, suggesting that behavioral contrast was greater when positive and negative stimuli were more similar. Mackintosh (1974) and Malone and Staddon (1973) have also suggested such a relationship. This type of similarity effect could help to account for the present findings, since the addition of borderline stimuli introduced to the continuum a set of S- values more similar to the unchanged S+ values. Further research should evaluate the role of S+ and S- similarity and compare it with the more complicated stimulus context effects implicated by D. Blough's approach.

The present findings extend the generality of both behavioral and dimensional contrast. They provide additional evidence against additivity theory as a complete account of behavioral contrast and offer tentative support for D. Blough's model.

## REFERENCES

- Beninger, R. J., & Kendall, S. B. Behavioral contrast in rats with different reinforcers and different response topographies. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 267-280.
- Berkley, M. A., & Kling, J. W. A small animal coupler with vertical movement compensation. *Physiology and Behavior*, 1967, 2, 315-316.
- 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.
- Blough, D. S. The dimensional contrast effect and its theoretical implications. In J. Baerwaldt & G. McCain (Eds.), *Recent developments in learning theory*. Stamford, Conn.: Greylock, in press.
- Catania, A. C., & Gill, C. A. Inhibition and behavioral contrast. *Psychonomic Science*, 1964, 1, 257-258.
- Essock, S. M., & Blough, D. S. Effects of stimulus spacing on steady state gradients of inhibitory stimulus control. *Animal Learning and Behavior*, 1977, 5, 174-176.
- 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.
- Gutman, A., Sutterer, J. R., & Brush, F. R. Positive and negative behavioral contrast in the rat. *Journal of the Experimental Analysis of Behavior*, 1975, 23, 377-383.
- Hearst, E., & Gormley, D. Some tests of the additivity (autoshaping) theory of behavioral contrast. *Animal Learning and Behavior*, 1976, 4, 145-150.
- Hinson, J. M., & Staddon, J. E. R. Behavioral competition: A mechanism for schedule interaction. *Science*, 1978, 202, 432-434.
- Innis, N. K. Contrast effects in multiple fixed-interval reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 233-242.
- Keller, K. The role of elicited responding in behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 249-257.
- Mackintosh, N. J. *The psychology of animal learning*. London: Academic Press, 1974.
- McSweeney, F. K., & Norman, W. D. Defining behavioral contrast for multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1979, 32, 457-461.
- Malone, J. C., & Staddon, J. E. R. Contrast effects in maintained generalization gradients. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 167-179.
- Rescorla, R. A., & Wagner, A. R. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory*. New York: Appleton-Century-Crofts, 1972.
- 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.
- Schwartz, B. Stimulus-reinforcer contingencies and local behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 297-308.
- Schwartz, B., & Gamzu, E. Pavlovian control of operant behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

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