JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1983, 39, 427-435 NUMBER 3 (MAY)

LOCAL CONTRAST IN MULTIPLE SCHEDULES: THE EFFECT OF STIMULUS DISCRIMINABILITY

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A three-ply multiple schedule assessed responding in a standard component as a function of the just-preceding schedule. The principal experimental condition was the difference among the wavelengths signaling the schedule components. Only the pigeons working in a narrow wavelength range showed persistent positive local contrast; that is, response rate during the standard component was higher when that component followed extinction than when it followed itself. Birds in both narrow- and medium-range groups showed persistent negative local contrast; that is, rate was lower following a relatively rich component. The dissipation of positive contrast appeared to be most clearly related to the establishment of differential responding. Negative contrast was inversely related to wavelength differences. Theories pertaining to contrast must account for the role of discrimination in both positive and negative types.

Key words: positive local contrast, negative local contrast, stimulus discrimination, stimulus similarity, key peck, pigeons

In learning experiments, contrast effects occur when the response measure in a given condition depends on the value of alternative conditions. The present research considers one form of behavioral contrast, known as induction (Pavlov, 1927), transient contrast (Nevin & Shettleworth, 1966), or local contrast (Schwartz & Gamzu, 1977). This effect, which I shall call local contrast, can be seen in response patterns during multiple schedules of reinforcement. Contrast is positive when rate during a constant component increases following a component associated with a leaner schedule of reinforcement. Negative contrast is seen as decreased responding following a richer reinforcement schedule.

Studies of local contrast have assessed its presence by differing criteria. One refers overall response rate during a given schedule component to the schedule in the just-preceding trial. The second considers the response pattern within a component; it refers rate at the component's onset to rates during subsequent segments of the trial. This paper will identify the first measure as between-component (BC) contrast and the second as within-component (WC) contrast. Although the two measures may describe the same phenomenon, research has not clarified this relationship.

A curious result, mentioned in a number of reports, is the tendency for contrast to dissipate with training. In their investigation of positive and negative local contrast, Nevin and Shettleworth (1966) chose the adjective "transient" to describe the decline in these effects over sessions. More recent reports (Gonzalez & Champlin, 1974; McLean & White, 1981) have also referred to the decline in local contrast as discriminations become established. Williams (1981) distinguished between the roles of the preceding- and following-schedule components as determinants of contrast. His findings suggest that the effects attributable to the preceding schedule are transient, although those attributable to the following component persist.

If discrimination performance affects the magnitude of contrast, then stimulus differences should also be important. Indeed, Pavlov (1927) observed increases in contrast when new, more difficult discriminations were introduced, and Nevin and Shettleworth (1966) noted that local contrast recurred when conditions were changed. In his review, Mackintosh (1974) discussed effects of stimulus similarity

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This research was supported by Grant BNS 80-255515 from the National Science Foundation. I am indebted to Donald S. Blough for his advice and encouragement. The figures were prepared with the aid of a computer program described by Hayes (1981). Send reprint requests to Patricia M. Blough at the Department of Psychology, 89 Waterman St., Brown University, Providence, Rhode Island 02912.

and suggested that contrast would be greatest when generalization between schedule components was partial; that is, contrast would be most pronounced when discrimination was neither very good nor very poor.

Studies of stimulus similarity and contrast have not clearly established the relationship suggested by Mackintosh. Hearst (1969) has shown a positive relationship between stimulus similarity and overall contrast, but Mackintosh, Little, and Lord (1972) found greater overall contrast when stimuli signaling the schedule components were more dissimilar. A series of experiments by Malone and his colleagues (Hinson & Malone, 1980; Malone, 1976; Malone & Staddon, 1973) have examined between-component local contrast effects in paradigms that included several stimuli along line-tilt continua. Evidence from these studies suggests that local contrast depends on the physical similarity between the stimuli signaling adjacent components. Some, but not all, of this evidence indicates that stimulus similarity enhances contrast.

The present experiment examined systematically the effect of stimulus discrimination on local contrast. The independent variable was the physical separation among monochromatic lights along a discriminability continuum. The design permitted quantitative assessment of both positive and negative contrast over the course of discrimination training. The analysis employed both between-component and within-component measures.

METHOD

Subjects

Eighteen White Carneaux pigeons, approximately 5 to 6 years of age, served. Prior to this experiment, all birds had participated in a one-semester undergraduate laboratory, where they were briefly exposed to various reinforcement schedules and discrimination-training procedures.

Apparatus

Three Lehigh Valley Electronics pigeon boxes were the subject chambers. The response key was located on the front panel just behind a circular opening, 25 cm above the floor and 2.5 cm in diameter. Operation of the response keys required a force of approximately .1 N. Below the center key, 12 cm above the floor, was a 5- by 6-cm opening for a food tray. The panel also contained two side keys, which were masked or unlit. Stimulus lights were conducted through a fiber optics light pipe, 3 mm in diameter and mounted just behind the response key. The houselight was a 6-V lamp mounted 7 cm above the center key. An opaque shield directed the light toward the ceiling. Behind the front panel was the food magazine and a loudspeaker that delivered white masking noise. Fans ventilated the boxes and provided additional masking noise. The subject chambers were located in a separate room, apart from additional optical and electrical equipment.

A Bausch and Lomb 250-mm grating monochromator controlled stimulus wavelength; its entrance and exit slits were set to provide a half-band width of 17 nm. The light source was a General Electric T10 6-V tungsten microscope illuminator lamp, operated at 16 A. Light from the monochromator passed through a balancing wedge and then through lenses that focused an image of the monochromator's exit slit on a neutral density wedge and again on a set of three adjacent shutters. One end of the fiber optics cable leading to a response key was located just beyond each of the shutters. A Light-Mate/Spot-Mate Photometer System provided calibration data; with this information, wedge settings were calculated so that all stimuli were equal in luminance for the pigeon (D. Blough, 1957). Luminance was approximately 6.2 cd/m^2.

A Digital Equipment Corporation PDP 11V03 computer controlled experimental contingencies, performed timing operations, and stored and analyzed data from daily sessions. Interfacing equipment included relays and stepping motors that controlled wedge and monochromator settings.

Procedure

The procedure was a modification of Nevin and Shettleworth's (1966) plan for their Experiment II. It assessed responding in a constant schedule component as a function of the variable component that just preceded it. Components were signaled by wavelength stimuli whose physical difference was varied across experimental conditions.

After preliminary magazine training, an autoshaping paradigm introduced the birds to the standard stimulus, a 600-nm keylight. A random-interval (RI) 2-min schedule programmed the onset of the light. Following the elapse of 8 sec or a key peck, whichever came first, the keylight went out and the food magazine operated. After approximately 60 responses, exposure to the standard experimental procedure began.

Sessions on the standard procedure consisted of a series of 54 cycles. Each cycle consisted of two phases separated by a 3-sec blackout. Phase A lasted approximately 2 min. Phase B lasted exactly 1 min and was followed by an intertrial interval approximately 10 sec in duration. Then the cycle repeated. During blackouts and intertrial intervals, the houselights and keylights were off; otherwise they were on continuously during the session.

During Phase A, one of three wavelengths could illuminate the key. The particular Phase A wavelength was selected according to a random block procedure such that each wavelength occurred equally often during a session, and the maximum length for a sequence at a given wavelength was four. Stimulus wavelength during Phase B was always 600 nm.

There were three experimental conditions, each associated with a different wavelength range in Phase A. All wavelength sets included 600 nm; a narrow-range condition employed 598 and 602 nm as alternative wavelengths; a medium-range condition employed 596 and 605 nm, and a wide-range condition used 567 and 625 nm. For each condition the alternative values were chosen so that they would be equally different from 600 nm in terms of discriminability units (Wright, 1978). For example, although the physical separation between 600 and 625 nm is less than that between 600 and 567 nm, the two distances should be equally discriminable.

Early sessions gradually increased in length as the birds went through a progression of RI schedules whose average duration increased. The subjects were ready for the experiment proper when they responded regularly through a 54-cycle session on the constant schedule, RI 300-sec, where the shortest interval was 1 sec. Magazine time was 4 sec for two chambers; the birds working in the third chamber had a nominal 5-sec magazine time, since the food tray was sluggish. During reinforcement the food tray was illuminated by its own light and responses were not recorded.

The experiment proper consisted of baseline and testing periods. During baseline, the reinforcement schedule was always RI 300-sec. Baseline continued until all subjects in a group had met the criterion described by Spealman and Gollub (1974). This criterion, applied to overall rate during the Phase-B periods, required (1) that birds run for at least 15 sessions, (2) that for the final nine sessions the median rate taken over sets of three sessions should not describe a regular trend, and (3) that there should be at least two reversals in this nine-value sequence.

During the ensuing testing period, the reinforcement schedules during Phase A were changed so that each wavelength had a unique association with a schedule. Table 1 summarizes the relationship between stimulus and schedule during both baseline and testing periods. Note that the schedule during Phase B remained constant throughout the experiment and that 600 nm always signaled RI 300-sec regardless of the phase in which it appeared. Testing continued until the stability criterion described above was met. However, here the criterion was applied to an overall discrimination index (DI), which related responding during RI 30-sec to the mean of that rate and rate in extinction.

Six birds ran in each of the three experimental conditions. In each group the longest wavelength signaled the richest schedule for three birds; for the other three subjects, the

Table 1

Association Between Wavelengths and Reinforcement Schedules

	Baseline		*Testing*	
Wavelength[a]	*Phase A*	*Phase B*	*Phase A*	*Phase B*
1	RI 300-sec	—	RI 30-sec	—
2	RI 300-sec	RI 300-sec	RI 300-sec	RI 300-sec
3	RI 300-sec	—	Extinction	—

[a] Wavelength 2 was always 600 nm. Wavelengths 1 and 3 varied among conditions (see text and Table 2).

Table 2

Mean Responses per Minute over Final Sessions

		Baseline						*Testing*					
		A Phase			*B Phase*			*A Phase*			*B Phase*		
Bird	*Wavelength 1*[a]	A_1[b]	A_2	A_3	B_1[c]	B_2	B_3	A_1	A_2	A_3	B_1	B_2	B_3
103	602	42	41	39	40	40	40	64	57	24	49	54	61
315	602	88	84	82	84	85	88	181	153	97	143	157	177
386	602	122	119	115	114	118	114	233	146	49	118	147	154
274	598	44	43	45	43	42	42	112	84	27	65	81	104
379	598	33	33	34	33	32	34	98	55	18	49	52	60
952	598	67	68	67	68	69	68	105	77	39	71	73	81
438	605	49	51	48	52	49	51	134	70	10	68	68	75
399	605	78	87	73	86	88	83	116	61	6	74	84	72
346	605	56	53	55	54	52	53	70	51	8	32	38	22
291	596	72	67	67	65	66	70	84	62	11	53	59	60
284	596	30	29	30	28	29	30	48	45	7	42	44	45
957[d]	596	31	31	29	32	30	36	101	56	6	48	54	61
568	625	62	64	73	67	63	55	88	67	22	22	66	74
868	625	28	31	30	32	31	29	64	26	2	30	26	21
984	625	58	57	49	63	58	62	106	100	5	102	96	90
217	567	37	35	39	39	35	35	62	52	22	52	48	59
328	567	28	32	35	32	30	31	59	32	12	30	31	38
553	567	63	57	58	53	51	50	101	77	27	81	74	82

[a] Text describes alternative wavelengths in the set of 3 that comprised a condition. Table 1 shows association between wavelength and reinforcement schedules.

[b] Letter denotes phase; numeral denotes wavelength.

[c] Numeral denotes wavelength in just-preceding component.

[d] Baseline showed unusual variability. Figures based on 6 days prior to a sudden rate drop.

shortest wavelength signaled the richest schedule. Table 2 shows the relationship between birds and conditions. It also shows the abbreviations used below to describe specific schedule components.

RESULTS

Final response rates are summarized in Table 2. These values are averages over the sessions that met the stability criterion. Occasional computer failure resulted in loss of some Phase-A data; thus in a few cases means for that phase are based on six to eight of the nine criterion sessions. Rate calculations do not include reinforcement time.

Conditions in B2 were unchanged during the experiment, since the current and just-preceding reinforcement schedules in this condition were always RI 300-sec. Many of the birds showed rate increases during B2 in the testing compared with the baseline periods. The rate change was significant only for the narrow-range condition, $t(5) = 3.0$, $p < .05$. This effect is unlike overall positive contrast, since overall reinforcement rate increased from baseline to testing. Positive overall contrast is ordinarily associated with a decrease in overall reinforcement. It is possible that introduction of differential reinforcement, by improving stimulus control, led to more precise direction of responses toward the key (Williams, 1981).

Measures used for further data analysis quantified between- and within-component contrast. Values labeled BC (between component) compare response rate during the constant reinforcement schedule when it was preceded by an unlike component to response rate when it was preceded by itself. Positive BC contrast, defined by the ratio B3/B2 (Table 2), was seen when that ratio exceeded 1.0. Negative BC contrast, defined by the ratio B1/B2, was seen when that ratio was less than 1.0.

Contrast values labeled WC (within component) compare response rate during the initial 20 sec of the component to overall rate during that component. Within-component contrast was positive when the preceding Phase A schedule was extinction and when this ratio exceeded 1.0; it was negative when the preceding schedule was RI 30-sec and when the ratio was less than 1.0.

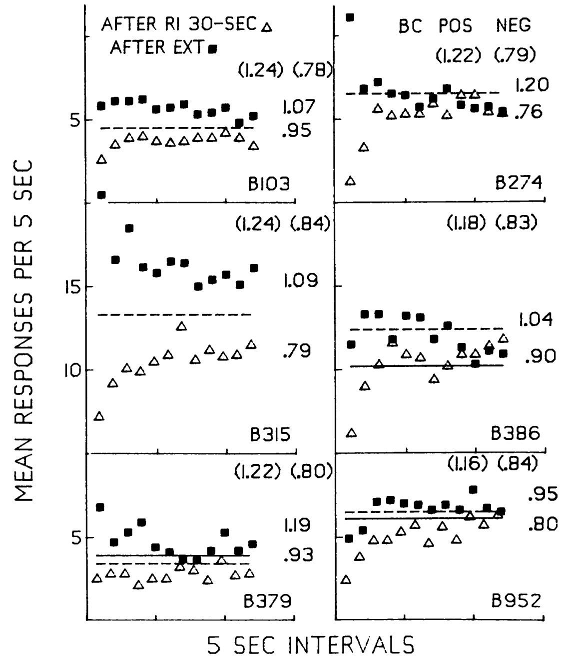

Fig. 1. Sample records of response rates within components. All birds were in the narrow-range group. Filled squares show mean rates over a single session in Phase B when it was preceded by extinction in Phase A. Unfilled triangles show mean rates in Phase B when it was preceded by RI 30-sec in Phase A. Horizontal lines show rates in reference components (Phase B when preceding Phase A schedule was RI 300-sec). Dashed and (if different) solid lines refer to filled- and unfilled-symbol functions, respectively. Obtained BC ratios are shown on each panel in parentheses; WC ratios describing filled (upper) and unfilled (lower) functions are to the right of those functions.

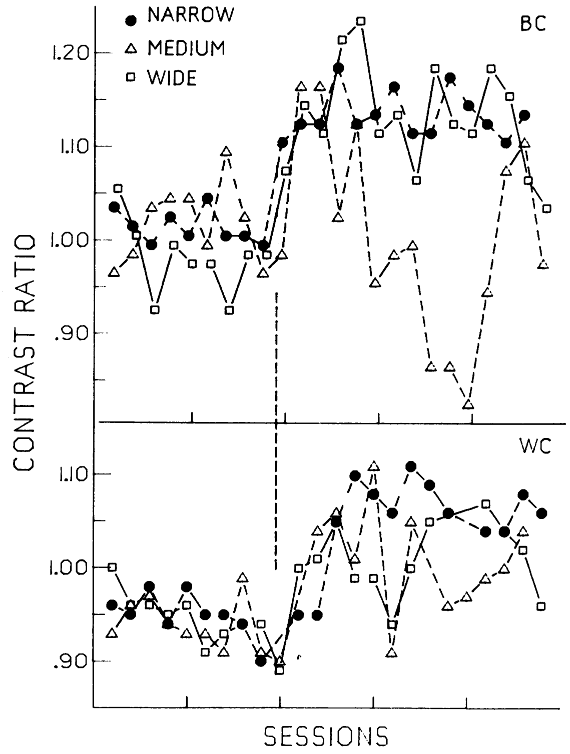

Fig. 2. Ratios exceeding 1.0 indicate positive local contrast, whose course is shown. Points are for individual sessions. The points to the left of the vertical dashed line show baseline, in which all schedules were RI 300-sec. The points to the right show discrimination testing, during which Phase A schedules were varied. Separate curves describe the three experimental conditions, which differed in the wavelength range covered by the signaling stimuli. The upper panels show BC contrast; WC contrast is shown in the lower panels. The graph shows only those sessions completed by all six birds in a group; thus, the rightmost points do not correspond to the final means that were the basis for the main data analysis.

Figure 1 illustrates these contrast measures with sample data from the birds in the narrow-range condition. The response rates shown here are means for one test session and show responses during successive 5-sec periods in Phase B. Between-component contrast appears as a difference between the overall level of the curves and the horizontal lines that show rate in Phase B when the preceding Phase A schedule was also RI 300-sec. The data were selected from instances in which positive and negative BC contrast were approximately equal. Within-component values appear in changes in rate across 5-sec intervals.

Figure 2 describes the course of positive local contrast during discrimination testing. Both BC and WC measures show clear positive contrast for the condition in which stimuli were most similar. Early in testing that group's function rose well above baseline and above the 1.0 ratio, and the effect was sustained. Contrast also appeared during early discrimination sessions for the medium- and wide-range groups. However, the effect became variable (medium-range group) and disappeared (wide-range group). T tests for repeated measures compared mean contrast ratios during the final, stable discrimination sessions to equivalent ratios during the final nine sessions of baseline. They were significant only for the narrow-range group; the difference was seen for both BC, $t(5) = 4.76$, $p < .005$, and WC, $t(5) = 5.10$, $p < .004$, measures. The data in Table 2 are the basis for these statistics; Figures 2 and 3 do not show all of the final sessions.

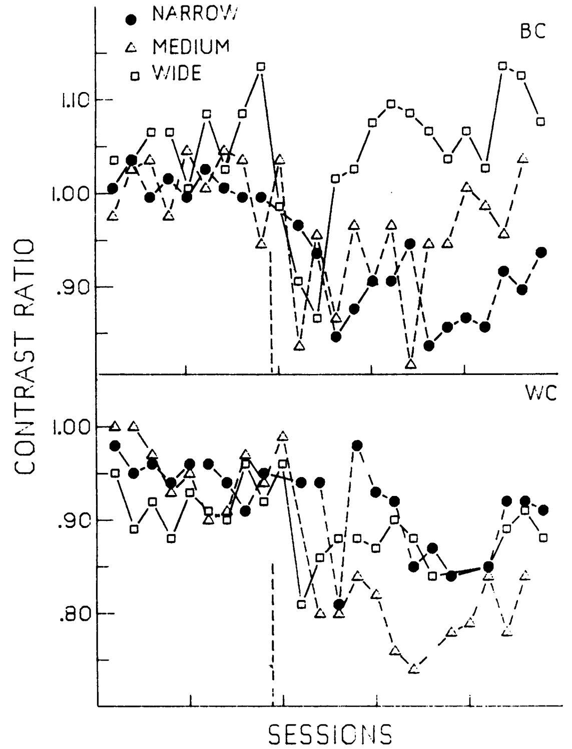

Fig. 3. Ratios below 1.0 indicate negative local contrast, shown in the same form as the data in Figure 2.

Figure 3 describes the course of negative local contrast in an analogous fashion. Both measures showed marked negative contrast during early testing sessions. Although the effects appear to diminish, comparisons between final baseline and discrimination sessions showed significant differences for both the small- and medium-range groups when the BC measures was used; for the small-range group, $t(5) = 3.4$, $p < .02$; for the medium-range group, $t(5) = 3.54$, $p < .01$. When the WC measure was used, the change was significant only for the medium-range group, $t(5) = 3.16$, $p < .02$.

Table 3 summarizes the amounts of local contrast for the three wavelength-range conditions. The bases of these values are the means, for each bird, over the nine stable discrimination sessions; the values shown are the means of those individual means. One-way analyses of variance assessed the effects of wavelength range on local contrast. There was no significant treatment effect on either of the positive measures, nor was there a significant effect on WC negative contrast. However, for BC negative contrast, the treatment effect was significant, $F(2,15) = 13.8$, $p < .001$. The order of this effect (Figure 3; Table 3, row 3) indicates that BC negative contrast and discriminability were inversely related.

Table 3

Mean Contrast Ratios

Preceding Component	*Measure*	*Stimulus Range*		
		Narrow	*Medium*	*Wide*
Extinction	BC	1.14[a]	.96	1.08
	WC	1.07	.97	1.00
RI 30-sec	BC	.89	.93	1.08
	WD	.89	.80	.89

[a] Values are means over final nine discrimination sessions averaged over groups. Since these data describe ratios, geometric means might be the preferred measure. However, since the present figures summarize a narrow range of values, the arithmetic and geometric means are nearly identical.

The BC and WC measures could describe the same result. For example, when a lean component follows extinction, the initial response rate increase (WC contrast) may cause the average rate in that presentation to exceed the rate when the preceding component is also lean (BC contrast). In Figure 1, the top right panel exemplifies such a case. The relationship between these measures is not logically necessary, however. For example, the lower right panel of Figure 1 shows an instance of positive BC contrast when initial rate was relatively low. Comparison between the top and bottom panels of Figure 2 indicates many similarities between the courses of the two measures. Correlation, based on final means for the 18 birds, showed a strong significant relationship between BC and WC measures of positive contrast, $r = .79$.

In the case of negative contrast, the relationship between the two measures is less clear. For example, treatment effects seen for the BC measure were no longer significant when the WC ratio was examined. Comparing the upper and lower panels of Figure 3, note especially the presence of a difference between the narrow- and wide-range groups when the BC measure is used and the apparent absence of this effect for the WC measure. The correlation between the two negative measures, again based on the final means for the 18 subjects, was small ($r = .30$) and not significant. Although rate enhancement at the transition between less- and more-favorable schedules may account for most of positive BC contrast, an analogous depression did not seem to account for much of the negative BC effect. The lower left panel of Figure 1 illustrates strong BC and weak WC contrast.

The WC measure is arbitrary in that it emphasized transitional effects during the first 20 sec of a component presentation. The measure could be more appropriate for positive than for negative contrast. For example, the dissipation of negative contrast could take longer. However, systematic examination of functions like those in Figure 1 showed no clear differences in the time course of the two effects.

Although physical similarity was the manipulated variable, contrast may relate more closely to the extent to which the birds actually discriminated among the wavelength stimuli. Figure 4 (left panel) relates positive contrast to a discrimination measure based on performance in the relevant components during Phase A. Considering just the small- and medium-range groups, there was a clear correspondence between physical similarity and discrimination performance; further, the poorer discrimination (and greater similarity) was associated with more positive contrast. The performance of the birds in the wide-range group helped to separate the performance from the stimulus variables, however. Four of these six subjects discriminated rather poorly. The fact that these subjects showed more BC contrast suggests that discrimination performance is indeed an important variable.

The center panels of Figure 4 illustrate a corresponding analysis using final rate in extinction as the measure of performance. Again, there was a distinction between the narrow- and medium-range groups, with the latter showing lower extinction rates and less positive contrast. Comparisons among the subjects in the wide-range group implicate a performance factor, since higher extinction rates were associated with greater positive BC contrast.

The right panel of Figure 4 shows the relationship between discrimination performance and negative contrast. Rate differentials between rich and lean schedules were small, the DIs ranging from .51 to .71, and there was no strong relation to stimulus similarity or to amount of contrast.

DISCUSSION

The present experiment demonstrated and quantified clear positive and negative local contrast. The data are consistent with and extend others that implicate discriminability (e.g., Hinson & Malone, 1980; Malone, 1976). When stimulus differences were small, both positive and negative local contrast persisted

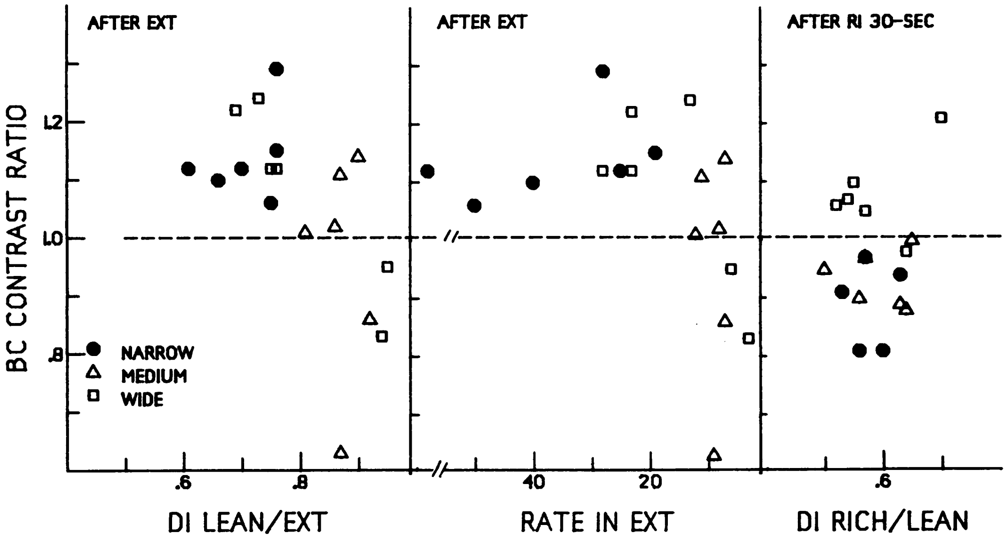

Fig. 4. Relationship between local contrast and discrimination performance for each of the experimental conditions. Data are means over the final stable sessions. The left panel relates BC "positive" (B3/B2) contrast to a discrimination index (DI) defined as A2/A2 + A3 (Table 2). The center panel relates "positive" contrast to responses per minute in the extinction component of Phase A (A3). The right panel relates "negative" contrast (B1/B2) to a DI defined as A1/A1 + A2. A dashed line sets the reference for no contrast.

throughout the course of discrimination learning. This evidence was strongest when the BC measure was used. For somewhat larger stimulus differences, only negative contrast persisted. Performance of the wide-range group was variable, and there was no strong evidence for persistent contrast.

Although numerous other studies have shown local contrast, between-subject variability is a frequent problem. One source of this variability could be individual differences in discrimination learning. Previous studies have used large stimulus differences, presumably discriminable by all subjects, but perhaps less well learned by some than by others. The present study purposely induced difficult discriminations; in fact, generalization studies (e.g., P. Blough, 1972) indicate incomplete discrimination among stimuli in the narrow range even after extensive practice. The lights used in the "medium range" were still very similar compared to stimuli employed in most studies of contrast.

Because contrast persisted in the narrow-range group, habituation cannot account for the decline over sessions seen in this and other studies of contrast (e.g., McLean & White, 1981; Nevin & Shettleworth, 1966). Changes in within-component patterning (WC measure) cannot be attributed to anticipation of the following schedule (Williams, 1981), which was not predictable in the present design.

For positive contrast, the data suggest that discrimination performance is more important than physical similarity. Although these factors were confounded in the narrow- and medium-range conditions, the variability among subjects in the wide-range group helped dissociate them. Hinson and Malone (1980) also distinguished between stimulus and performance factors, concluding that stimulus factors are important initially, but that contrast depends on response rate differential later in training. The present study extends this line of research (see also Malone, 1976; Malone & Staddon, 1973) to a paradigm that used fewer stimuli and thus was less likely to involve dimensional contrast effects (D. Blough, 1975; P. Blough, 1980).

Negative contrast has been more difficult to demonstrate and to understand (Schwartz & Gamzu, 1977). In order to observe it, a nonzero baseline is required, making rate differentiation harder to achieve. The present design assessed negative contrast with sequences of schedules that were more similar than the sequence that assessed positive contrast. The low discrimination indices seen in the comparison between rates in the rich and lean schedules did not clearly relate to stimulus similarity (Figure 4, right panel). Since negative BC contrast was significantly related to stimulus range, the data suggest that stimulus factors may be important when differential performance is weak. This conclusion is consistent with Hinson and Malone's, noted above.

A complete explanation of local contrast should account for both positive and negative directions and for discrimination factors. Several two-process accounts, which distinguish between discrimination learning and its classically-conditioned, motivational, or emotional by-products, are promising. For example, Schwartz and Gamzu's (1977) additivity model of contrast has received considerable empirical support. According to this view, classical associations between reinforcers and their signaling stimuli elicit key pecks from pigeons, and these elicited responses are added to instrumental responses maintained by the response-reinforcer association. Recently Schwartz (1978) concluded that this model accounts best for local, rather than overall, positive contrast, since elicited responses occur mainly at the onset of the new schedule component. The additivity model depends on spatial contiguity between the stimulus and the response manipulandum and is thus appropriate for the present arrangement. However, there is no evidence to suggest that elicited responses diminish when the stimuli are well discriminated. Thus the additivity model does not presently account for the stimulus factors seen here.

Rachlin (1973) applied a similar analysis to negative contrast, noting that stimuli signaling nonreinforcement can inhibit responses. If inhibition were associated with a competing response such as withdrawal, the behavior might have a slower time course and occupy more of a schedule component. Thus it would be less sensitive to the WC measure used here. Although our records did not reveal differences in response distributions associated with positive and negative contrast, systematic observations of response topologies might clarify Rachlin's application of additivity theory.

Again, however, it is difficult to reconcile the discriminability effect with this approach to contrast.

A discussion by Mackintosh (1974) suggests a process consistent with the discrimination effect. A negative stimulus, if it is sufficiently similar to a positive one, may acquire excitatory properties through generalization. Through its primary association with nonreinforcement, the stimulus retains inhibitory properties as well. The inhibitory effect preserves discrimination in a negative situation; however, in an ensuing positive condition, the inhibition diminishes, leaving the excitatory effect to enhance responding. This discussion accounts for positive contrast and is reminiscent of others that suggest opponent processes with different time courses (e.g., Solomon & Corbit, 1974). However, a prediction of negative contrast would seem to require a reversed relationship between the time course of "positive" and "negative" processes.

The present findings bear on recent conclusions by McSweeney (1982), who found parallel component duration effects on positive and negative contrast. Despite some inconsistencies, the results reported here suggest similar parallels in the effect of stimulus variables. Further research should investigate positive and negative contrast under more comparable conditions. Should the parallel improve, attempts to account for discrimination effects must address contrast in both directions.

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Received July 30, 1982
Final acceptance November 2, 1982