JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1992, 58, 303-312 NUMBER 2 (SEPTEMBER)

INVERSE RELATIONS BETWEEN PREFERENCE AND CONTRAST

BEN A. WILLIAMS

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Pigeons were trained on a multiple schedule in which two target components with identical reinforcement schedules were followed by either the same-valued schedule or by extinction. Response rate increased in both target components but was higher in the target component followed by extinction, replicating previous findings of positive anticipatory contrast. A similar design was used to study negative contrast, in that the two target components were followed either by the same-valued schedule or by a higher valued schedule. Negative contrast occurred equally, on average, in both target components, thus failing to demonstrate negative contrast that is specifically anticipatory in nature. When the stimuli correlated with the two target components were paired in choice tests, the pattern of preference was in the opposite direction. For the positive contrast procedure, no significant preference between the two target stimuli was evident. But for the negative contrast procedure, preference favored the stimulus followed by the higher valued schedule. The results demonstrate a functional dissociation between positive and negative contrast in relation to stimulus value. More generally, the results demonstrate an inverse relation between response rate and preference and challenge existing accounts of contrast in terms of the concept of relative value.

Key words: behavioral contrast, anticipatory contrast, multiple schedules, choice, context of reinforcement, key peck, pigeons

Reviews of research on behavioral contrast (Freeman, 1971; Williams, 1983) have concluded that the major variable controlling response rate in a multiple schedule is the relative rate of reinforcement associated with the discriminative stimuli of the components of the schedule. The most natural interpretation of this relationship is that the reinforcement "value" of the schedule correlated with a particular component is relative to its context: In lean reinforcement contexts, a given reinforcement schedule is more effective in strengthening behavior than is the same schedule in a richer reinforcement context.

Despite the intuitive appeal of this "relative value" interpretation of contrast, there is substantial evidence against its validity. Williams (1991) provided a direct test by presenting pigeons with a four-component multiple schedule in which two target components had identical schedules but were followed by different components of either higher or lower value. After obtaining the usual anticipatory contrast effect (cf. Williams, 1979), the stimuli associated with the two target components were presented together during probe tests. Despite response rate during training being higher in the target component followed by extinction (EXT) than in the target component followed by a higher valued schedule, response rates during the probe trials were the reverse: The component followed by the higher valued schedule was preferred. Similar dissociation between response rate and reinforcement value has been obtained by Nevin, Smith, and Roberts (1987) and by Tota (1990)[1] using resistance to change as the measure of reinforcement value. That is, greater resistance to change occurred in the components of a multiple schedule that were associated with the lower response rates. Apparently, therefore, the higher response rates observed during contrast procedures do not correspond to a greater value of the components associated with those higher rates.

The present study was a further study of the basic procedure used by Williams (1991) to investigate the critical determinants of the obtained preference results. The study of Wil-

This research was supported by NSF Research Grant BNS 0010323 to the University of California, San Diego. The author thanks Bertram Ploog for his conduct of the experimental protocols. Reprint requests should be addressed to the author, Department of Psychology, UCSD, La Jolla, California 92093-0109.

[1] Tota, M. E. (1990). *Resistance to change in multiple schedules: Pavlovian influences.* Paper presented at the annual meeting of the Association of Behavior Analysis, Nashville, TN.

liams (1991) was atypical of most previous studies of behavioral contrast in that no change in relative rate of reinforcement occurred across the different phases of the experiment. Instead, differences in response rate during the target components were determined entirely by changes in the location of the higher and lower valued schedules in the sequence of component presentation. It is possible that contrast effects due to such sequential variables may have different properties than those produced by changes in overall relative reinforcement rate. Consequently, the present procedure followed a more conventional design. A baseline training phase was presented in which the schedules during all four components were equal, and then a contrast phase was presented in which one of the schedules was changed to a different value. Changes to higher or lower valued schedules were studied separately, to determine if the relation between preference and contrast effects with respect to response rate was different depending on whether positive or negative contrast was involved. Differences between positive and negative contrast would be expected on the basis of the analysis of contrast in other studies, in which contrast manipulations resulting from increasing versus decreasing reward value often have produced asymmetrical results (see Flaherty, 1982, for a review). For both procedures, two target components were maintained throughout training with identical reinforcement schedules, one of which was followed by the component correlated with the variable schedule and one of which was followed by the component correlated with a schedule that remained unchanged throughout training. The stimuli correlated with these two target components were then paired in preference tests presented at various points in training.

METHOD

Subjects

Eight experimentally experienced White Carneau pigeons were maintained at 80% of their free-feeding body weights by additional feeding, when necessary, after each experimental session.

Apparatus

Four identical three-key experimental chambers were used. They were 36 cm wide, 32 cm long, and 35 cm high. All walls were opaque gray plastic except the front, which was sheet aluminum. Mounted on the front sheet were three translucent response keys (2.5 cm diameter) 26 cm above the floor and 7.25 cm apart, center to center. Each key required a force of approximately 0.15 N to operate and could be illuminated from the rear by standard IEE 28-V 12-stimulus projectors. A 28-V 1-W miniature lamp was located 8.75 cm above each response key, and the right-most of these lamps provided general chamber illumination. Directly below the center key and 9.5 cm above the floor was an opening (5.7 cm by 5 cm) that provided access to a solenoid-operated grain hopper. When activated, the hopper was illuminated from above with white light by a 28-V 1-W miniature lamp. A 5-cm speaker was mounted above the center of the ceiling and provided continuous white noise throughout the experimental sessions. Experimental events in each chamber were controlled by microcomputers located in an adjacent room.

Procedure

Because all subjects were experienced, they were begun immediately on a four-component multiple schedule. The four components were arranged in pairs, such that Component A was always followed by Component X, Component B was always followed by Component Y, and the A-X and B-Y pairs were randomly alternated. Throughout training, Components A and B were 10 s in duration and Components X and Y were 30 s in duration. The schedules of reinforcement in Components A and B were always VI 2 min; the schedules during Components X and Y were either VI 2 min, extinction, or VI 30 s, depending upon the experimental condition.

The stimuli correlated with Components A and B were red and green keylights, which transilluminated the entire response key. Assignment of the colors to components was counterbalanced across subjects. These colors appeared randomly on the left and right response keys of the chamber, only one of which was illuminated at any given time. The stimulus for Component X was always a white vertical line on a dark background, and the stimulus for Component Y was always a white horizontal line. Both line orientations appeared on the center key.

Phase 1 of training was a baseline condition in which the schedule in all four components was VI 2 min. Experimental sessions contin-

ued for 56 min and included 42 presentations of each component. Training in Phase 1 continued for 20 sessions.

During Phase 2, the schedule during Component X was changed to VI 30 s for subjects assigned to Group 1 (R-67, R-64, R-65, R-70); for the remaining subjects assigned to Group 2 (R-69, R-62, R-59, and R-68), the schedule during Component Y was changed to EXT. Training continued for 30 sessions and was followed by 20 more sessions of baseline training (Phase 3) in which all schedules were again VI 2 min.

During Phase 4, the schedule during Component X was changed to EXT for Group 1, and the schedule during Component Y was changed to VI 30 s for Group 2. Training continued for 30 sessions. Finally, 30 additional sessions of baseline training were given during Phase 5.

Throughout training, test sessions occurred after every five sessions of regular training. During these test sessions, probe trials were occasionally interspersed into the regular sequence of multiple component presentations. These probe trials involved simultaneous presentation of the red and green colors correlated with Components A and B. The location of the colors on the left and right keys was randomly varied, with the constraint that each color occur in both positions an equal number of times over the course of the session. Probe trials were presented for the same 10-s durations as the presentations of Components A and B during regular training, and their respective reinforcement schedules (both VI 2 min) continued to operate as well. A total of eight probe trials was given during each test session, four of which followed presentation of Component X and four of which followed the presentation of Component Y. The regular multiple schedule was resumed after a probe trial, with Component A or B randomly assigned as the next component.

RESULTS

Figure 1 shows response rates during Components A and B for individual subjects across the different phases of the experiment. Components X and Y are not shown because they were generally consistent with expectations, in that response rate was monotonically related to reinforcement rate, being highest with the VI 30-s schedule and lowest during extinction.

If contrast occurred during both target components as a function of the change in reinforcement schedule in Components X and Y, response rate should have increased in both target components during Phase 4 for subjects in Group 1 and during Phase 2 for subjects in Group 2, relative to the surrounding baseline conditions. Similarly, response rates should have decreased during Phase 2 for subjects in Group 1 and during Phase 4 for subjects in Group 2. Alternatively, if contrast were due entirely to changes in the reinforcement schedule following a particular target component, the expectation for subjects in Group 1 is that Component A response rate should be lower than the baseline rates during Phase 2 and higher than the baseline rates during Phase 4, whereas Component B response rates should be similar to baseline during both Phases 2 and 4. For subjects in Group 2, Component B response rate should be higher than the baseline rates during Phase 2 but lower than the baseline rates during Phase 4, whereas Component A rates should be similar to the baseline rates during the corresponding two phases.

The obtained pattern of results was between these different predictions. The behavior of some subjects was governed primarily by the following schedule of reinforcement (e.g., R-65, R-59, R-69); that of others showed contrast effects in both target components with little differentiation according to which was followed by the variable schedule (e.g., R-68, R-62).

The effects of the schedule changes seen in Figure 1 are confounded for individual subjects by possible stimulus preferences and by general increases in response rate with continued training independent of the schedule changes. The effect of varying the schedule in either Component X or Y can be seen more clearly in Table 1, which shows the response rates during the last 10 sessions of Phases 2 and 4 (in which reinforcement rate was varied) and the mean of the last five sessions of each baseline phase surrounding these phases (i.e., the baseline comparison for Phase 2 was the mean of the last five sessions of Phases 1 and 3, and the baseline comparison for Phase 4 was the mean of the last five sessions of Phases 3 and 5).

All 8 subjects exhibited a positive contrast effect during both target components (Table 1). All subjects also showed a negative contrast effect during the target followed by the vari-

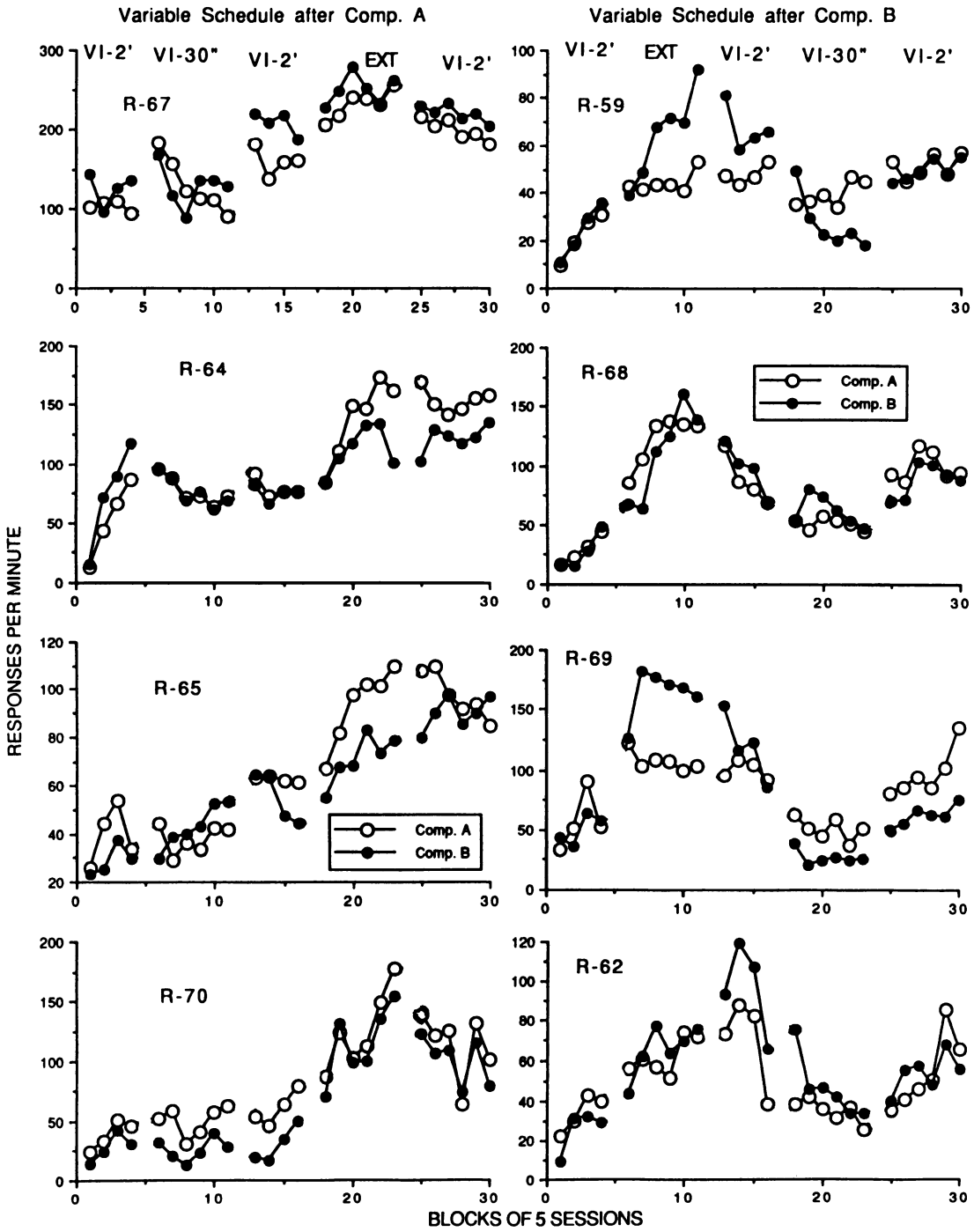

Fig. 1. Absolute response rate during the two target components as a function of the variable schedule, as indicated at the top of each side of the figure. Subjects on the left side of the graph always received the variable schedule after Component A; subjects on the right side always received the variable schedule after Component B.

Table 1

Response rates (responses per minute) for individual subjects during the contrast phases and the surrounding baseline phases, presented separately for the target component followed by the variable schedule ("variable follows") and for the target component followed by the same schedule throughout training ("same follows"). Also shown are the choice proportions taken from the two probe sessions during the corresponding period of training.

	Variable follows		Same follows		Preference for variable follows	
Subject	Baseline	Contrast	Baseline	Contrast	Baseline	Contrast
Positive contrast						
R-67	172	243	196	247	.38	.23
R-64	117	168	106	118	.48	.59
R-65	73	106	71	76	.63	.52
R-70	90	163	65	145	.68	.56
R-59	51	81	42	47	.62	.46
R-68	59	150	57	134	.54	.74
R-69	77	164	72	101	.32	.06
R-62	47	72	39	73	.66	.50
M	85	143	81	118	.54	.46
Negative contrast						
R-67	127	101	161	132	.49	.70
R-64	82	68	97	65	.46	.60
R-65	47	42	37	53	.65	.94
R-70	63	60	40	29	.63	.90
R-59	60	21	55	46	.58	.87
R-68	80	50	81	48	.44	1.00
R-69	80	25	113	44	.25	.72
R-62	61	34	52	31	.66	.86
M	75	50	79	56	.52	.82

able schedule, whereas 7 of the 8 subjects produced negative contrast in the alternative target component as well. Clearly, therefore, both positive and negative contrast were reliably obtained in both target components and were thus not dependent, at least entirely, on the location of the variable schedule in the component sequence.

Of major interest is whether the size of the contrast effects varied as a function of whether the target component was or was not immediately followed by the variable schedule. For the positive contrast comparison, there was little difference between the two target components during the baseline phases; this difference was not statistically significant ($t < 1$). For the contrast phase, response rate was substantially higher during the target component followed by extinction than that followed by the VI 2-min schedule (mean difference of 25 responses per minute); this difference was statistically significant, $t(7) = 3.12$, $p < .05$. In terms of individual subjects, 6 of the 8 subjects showed a larger contrast effect during the target component followed by the variable schedule than during the target always followed by the VI 2-min schedule. The size of the difference between the contrast and baseline phases for the two target components was also statistically significant, $t(7) = 2.62$, $p < .05$). Thus, there was a significant anticipatory positive contrast effect independent of the overall contrast effect that occurred during both target components.

For the negative contrast comparison, there was no reliable difference in the size of the contrast effect for the two target components. There was again no reliable difference between the two components during the baseline phases ($t < 1$), and there was also no reliable difference during the contrast phase ($t < 1$). In terms of individual subjects, the size of the negative contrast effect was larger during the target followed by the VI 30-s schedule for only 3 of the 8 subjects. Therefore, the failure to obtain statistically significant anticipatory negative contrast cannot be ascribed to a failure of statistical power, because a majority of the subjects displayed a difference in the wrong direction.

Table 1 also shows the results of the probe tests given during the periods corresponding to the response-rate data shown for the regular training procedure. The probe data shown for the baseline phases came from the test sessions following the last day of the baseline training phases surrounding the particular contrast comparison, whereas the probe data from the contrast phases came from the test sessions following the 25th and 30th training session of each contrast phase. The measure that is presented is the preference for the target stimulus that was followed by the variable schedule.

During the baseline phases there was no reliable preference for either target stimulus, as would be expected because of the equal schedules during all four components and the counterbalancing of stimuli across subjects. During the positive contrast phase, there was a slight preference for the target stimulus followed by the constant VI 2-min schedule over the target followed by EXT, in that the mean preference for the target followed by the variable schedule was .46. However, preference values above .50 occurred for 4 of the 8 subjects, so that this value was not significantly less than .50. The reduction in preference from the baseline value of .54 to .46, although somewhat more reliable across individual subjects (occurring for 6 of 8 subjects), was also not statistically significant, $t(7) = 1.49$, $p > .10$. Thus, the reliable anticipatory positive contrast effect that occurred with respect to the response-rate measure was not accompanied by a reliable change in preference for the target stimulus associated with the contrast effect.

For the negative contrast manipulation, the stimulus followed by the variable schedule was again not reliably preferred during the baseline phase, but now was preferred by all 8 subjects during the contrast phase, with a mean value of .82, which was significantly different from .50, $t(7) = 6.72$, $p < .05$. The increase in preference from baseline to contrast phase was also statistically significant, ($t(7) = 6.05$, $p < .05$. Thus, despite the absence of a reliable anticipatory negative contrast effect, preference for the stimulus leading to the VI 30-s schedule was greatly enhanced.

A final comparison from the present data concerns changes in response rate during Components X and Y. For each subject one of these components remained correlated with the same VI 2-min schedule throughout training, while the schedule for the other was changed to EXT, VI 2 min, and VI 30 s. Of some interest is whether contrast occurred during the unchanged component, given that it was never temporally adjacent to the component with the variable schedule. Of special interest is whether the role of temporal adjacency differs for positive versus negative contrast. Table 2 presents the relevant data by showing the response rates during the unchanged component (Y for Group 1, X for Group 2) in the same format as shown in Table 1 for the target components. For the conditions in which the schedule in the alternative component was changed to EXT (designated as the positive contrast condition), response rate increased slightly above the baseline level for 5 of the 8 subjects, increased substantially for 1 subject, and deceased for 2 subjects. The resulting mean value was similar to the mean value from the baseline training phases. Thus, there was no consistent positive contrast effect when the unchanged component was not temporally adjacent to the component correlated with EXT. For the negative contrast condition, response rate during the constant component decreased for 7 of the 8 subjects, often substantially. The resulting mean difference between the negative contrast phase and the surrounding baseline phases was 15 responses per minute. This difference was statistically significant, $t(7) = 3.63$, $p < .05$. Thus, negative contrast did not depend on the unchanged component being temporally adjacent to the richer schedule. It should be noted that any comparison of the size of the contrast effects in Tables 1 and 2 is confounded by the use of different stimuli, because the target component stimuli (red and green colors) were clearly more different from the stimulus associated with the variable schedule (a vertical or horizontal line) than was the stimulus associated with the unchanged following schedule (the alternative line orientation). The comparison is also confounded by differences in component duration, in that the target components were 10 s and the unchanged following schedule was 30 s.

DISCUSSION

In previous studies that have investigated the contribution of anticipatory contrast to the total contrast effect obtained in multiple schedules, contrast effects independent of anticipatory contrast have either occurred unreliably

across subjects or were small in magnitude (e.g., Williams, 1988, 1989; Williams & Wixted, 1986). Williams (1981) used a procedure similar to that presented here in that reinforcement rate was varied during one component of a three- or four-component schedule while all of the remaining schedules remained constant. Some change in response rate occurred during the target component not followed by the variable schedule, but the effect was highly variable and inconsistent across subjects (see Table 3 of that study). The present results were quite different, because they demonstrated robust positive and negative contrast effects for both target components, indicating a strong source of contrast independent of anticipatory contrast. Why the present study produced a different outcome is unclear, but one possibility is the manner of stimulus presentation. Williams (1981) always presented the stimuli in the same location, whereas the target stimuli here were randomly varied between two locations. Previous studies of local contrast have shown that contrast is enhanced by several types of variability, including the number of different stimuli that may precede a target (Malone, 1976) and the duration of the preceding stimuli (Hinson & Staddon, 1981). It is possible that variability of all types potentiates the occurrence of local contrast and that an increase in the degree of local contrast was responsible for the robust overall contrast effects obtained here. Unfortunately, no separate measurement of local contrast was made in the present study, so this account is only speculative. Nevertheless, the present data make clear that the relation between anticipatory contrast and overall contrast is not well understood.

Although the present results differ from previous studies in the relation between overall contrast and anticipatory contrast, they are consistent with previous findings regarding the relation between anticipatory contrast and stimulus preference. As in the study by Williams (1991), tests of preference between two stimuli leading to different following schedules of reinforcement favored the stimulus leading to the richer following schedule, whereas response rates during presentations of the individual stimuli were in the opposite direction. Preference and contrast thus appear to be inversely related.

The present study goes beyond the previous study in showing that the inverse relation between contrast and preference depended upon the type of contrast effect involved. When the variable schedule was changed to EXT, significant positive contrast occurred in both target components, but this effect was substantially larger in the target component that immediately preceded the EXT component. But when the variable schedule was changed to VI 30 s, there was a significant negative contrast effect in both target components, but there was no significant difference between the two target components. Thus, there was clear evidence of positive anticipatory contrast, but there was no evidence of negative anticipatory contrast. It is difficult to interpret the failure to obtain the negative anticipatory contrast effect, because some subjects clearly did demonstrate the effect under some conditions (e.g., R-59 in Figure 1). However, the effect did not occur reliably across subjects.

The opposite pattern of results was obtained with the preference tests. When the variable schedule was changed to EXT, there was no reliable change in the preference for the target leading to EXT relative to the target leading to the baseline schedule. But when the variable schedule was changed to VI 30 s, there was a strong increase in preference for the stimulus leading to the VI 30 relative to the target followed by the baseline schedule. Thus, although the VI 30-s schedule failed to produce a significant negative anticipatory contrast effect, it did produce a strong increase in preference, whereas the EXT schedule produced a positive anticipatory contrast effect but no

Table 2

Response rate during the following component always correlated with the VI 2-min schedule (X or Y depending on subject) as a function of the change in reinforcement rate in the alternative following schedule. Shown separately are the response rates during the contrast manipulations and the surrounding baseline periods.

	Positive contrast		Negative contrast	
Subject	Baseline	Contrast	Baseline	Contrast
R-67	168	110	182	164
R-64	88	91	75	61
R-65	82	79	63	69
R-70	98	124	43	29
R-59	57	66	71	48
R-68	88	98	101	80
R-69	95	105	86	54
R-62	63	67	89	84
M	92	93	89	74

change in preference. This dissociation strongly suggests that the mechanisms underlying anticipatory contrast and preference are functionally independent.

The negative contrast results obtained with the present procedure are similar to those reported by Capaldi and Sheffer (1992), who used a consummatory licking procedure. They presented rats with saccharin mixed with either of two flavors, one of which was followed by access to chocolate milk and one of which was followed by no additional food. Consumption of saccharin was depressed for both flavors relative to a control group that did not receive the chocolate milk following either flavor, but there was no reliable difference in the amount of suppression as a function of which flavor preceded the chocolate milk. However, there was a strong preference for the flavor preceding the chocolate milk when both flavors were presented together in a choice test. Thus, like the present study, Capaldi and Sheffer demonstrated both negative contrast and conditioned stimulus preferences, and these effects differed with respect to their stimulus specificity. Although the negative contrast effect was not specific with respect to the particular stimulus that preceded the following high-value reinforcer, the conditioned taste preference was stimulus specific. The similarity of the present results to those of Capaldi and Sheffer (1992) suggests that any explanation for the present findings must be sufficiently general to encompass the consummatory response procedure as well.

The dissociation between positive and negative contrast that was obtained here is surprising when considered from the perspective that the procedural manipulations involved for both are changes in relative rate of reinforcement. Relative rate of reinforcement for the target components increased when the variable schedule was changed to EXT and decreased when the variable schedule was changed to the VI 30-s schedule. Previous analyses of contrast (e.g., Nevin, 1973) have treated relative rate of reinforcement as a unitary variable, in part because there appeared to be a continuous relationship between response rate and relative rate of reinforcement throughout the range of the variable. Such an assumption implies that positive and negative contrast should produce qualitatively similar effects.

The dissociation of positive and negative contrast manipulations is especially puzzling with respect to the preference tests. During the positive contrast manipulation, the subjects chose between a stimulus that led to a VI-2 min schedule and a stimulus that led to EXT. During the negative contrast manipulation, the choice was between stimuli that led to VI 30 s and VI 2 min. In both cases there was a clear difference in the value of the different following schedules, but only in the latter was a reliable preference effect obtained. These results suggest that relative rate of reinforcement in fact is not a unitary variable, and suggest instead that schedule interactions depend critically on the direction of schedule change. Of course, such a conclusion greatly complicates the analysis of contrast, especially with respect to quantitative descriptions that ignore the direction of change completely.

The inverse relation between contrast and preference obtained here and in the study by Williams (1991) and the corresponding inverse relation between contrast and resistance to change (Nevin et al., 1987) raise the question of whether all behavioral contrast effects have such an inverse relationship, or whether instead it is restricted to anticipatory contrast procedures. A sizeable portion of the total contrast effect in multiple schedules may be independent of the anticipatory contrast effect, as shown by the present finding of both negative and positive contrast in the target component that was followed by the constant schedule throughout training. The question is whether this more general form of contrast might be positively, rather than inversely, related to stimulus value, when value is assessed by a preference test.

Some evidence in favor of a positive relationship was reported by Bloomfield (1969), who presented pigeons with two different stimuli associated with identical reinforcement schedules but differing in whether they were alternated with a discriminated period of extinction. Stimulus A was alternated with extinction over 2-min cycles during 10-min blocks, and Stimulus B was presented continuously (at different times in the same session) for 10-min blocks. Higher response rates occurred to Stimulus A, indicating that contrast had occurred. When both Stimulus A and Stimulus B were presented together during preference tests, Stimulus A was preferred here as well. Bloomfield thus concluded that contrast occurred because the subject valued the food more during the stimulus alternated with

extinction. Unfortunately, the reasons for the conflict between Bloomfield's results and those reported here remain uncertain, because his report of the procedural details was so sketchy that no direct comparison can be drawn.

Other data suggestive of a positive relationship between contrast effects and changes in stimulus value were reported by Eisenberger, Frank, and Park (1975), who trained rats in a T maze in which forced exposure was given to one of the arms of the maze where either a constant amount of reward was presented on each trial throughout training or the amount of reward was changed to the same level after initial exposure to either a larger or smaller amount. For example, one group of rats received two pellets on each trial throughout training, whereas a second group initially received 16 pellets per trial and then had their amount reduced to two pellets. After the reward shift had occurred, the rats were given a choice between the alley associated with the shift and an alternative alley not previously associated with the reward. The result was that negative contrast effects due to a downward shift in reward produced a preference shift away from the old alley, whereas upward shifts in reward produced a preference shift in favor of the old alley. Apparently, therefore, incentive contrast effects in alleyways are positively associated with corresponding changes in stimulus value.

A related effect on discrimination learning was reported by Williams (1977). Pigeons were initially trained on a simultaneous red versus green discrimination in which one group received a 25% reward schedule for correct choices and a second group received 100% reward for correct choices. After the color discrimination was well learned, both groups had interspersed among the color discrimination trials a new discrimination between two form stimuli, for which a 100% schedule was presented for both groups. The rate of learning this new form discrimination was found to be inversely related to the reward rate for the already-learned color discrimination, in that faster acquisition occurred for the 25% reward group. Thus, there appear to be contrast effects in which leaner contexts of reinforcement increase the reward value of a stimulus, at least to the extent that reward value is indexed by rate of learning. How such effects are related to the present results remains unclear.

One possible interpretation of the inverse relation between stimulus value and contrast in the present anticipatory contrast procedure is that the preference relations were due entirely to the Pavlovian stimulus–reinforcer relation, but the contrast effects with respect to response rate were due to other variables. That the Pavlovian relation should produce an increase in preference for the stimulus leading to the higher valued following schedule is intuitively plausible. Moreover, there are data that demonstrate that this Pavlovian relationship can override the usual dynamics of anticipatory contrast when the stimuli in the target components are made the sole predictors of the different following schedules by presenting the same stimulus during the different following schedules (Williams, 1979, Experiments 2 and 3; Williams, 1990; also see Brown, Hemmes, Coleman, Hassin, & Goldhammer, 1982, for related autoshaping effects).

The key theoretical issue is why these Pavlovian effects were evident in the preference tests but were not evident during the regular training procedure with individual presentations of each component of the multiple schedule. That is, why should the presence of two stimuli, rather than only one, change the relation between the response rates for the two stimuli? One possibility is that the subject treats the choice tests differently than individual stimulus presentations, in that it responds to obtain the different following schedules rather than to obtain the value of the different stimuli themselves. But this interpretation seems implausible because there was never a contingency between responding during the target components and the onset of the different following schedules during training and because the component that followed the probe trials, regardless of the location of responding during the probe trials, was randomly assigned.

The major puzzle is not the preference results, which can be explained by the Pavlovian contingencies embedded in the procedure, but the occurrence of anticipatory contrast with respect to response rate. One possible interpretation is "conditioned frustration," in the sense that a cue for a pending period of extinction may elevate response rate during its presence. Such an interpretation was proposed by Leitenberg (1966) for the effects of signaled timeout periods. The fact that significant anticipatory contrast was obtained only when extinction was the following schedule provides some support for this possibility. If this inter-

pretation is correct, at least some forms of contrast may be explained by frustration theory, which was developed to explain the effects of nonreinforcement in entirely different procedures (e.g., Amsel, 1962).

Whatever the explanation of anticipatory contrast, the present findings of an inverse relation between stimulus value and response rate have implications that extend beyond the understanding of behavioral contrast. The present results, along with others (e.g., Picker & Poling, 1982), demonstrate that response rate cannot be taken as an index of reinforcement value when reinforcement value is indexed directly by choice tests. Accounts that explain the relation between response rate and reinforcement parameters in terms of changes in relative value, such as that of Herrnstein (1970), are thus suspect. Given that response rate is inversely related to choice in at least some contrast procedures, there is no reason to assume that response rate will be positively related to reinforcement value in other situations. The inverse relation between response rate and choice obtained here also challenges any theory of single-response situations based on the supposition that different response rates reflect choice between the behavior upon which reinforcement is contingent versus other behavior in the situation. Contrary to Tolman's famous dictum, the present results show that all behavior is not choice.

REFERENCES

Amsel, A. (1962). Frustrative nonreward in partial reinforcement and discrimination learning. *Psychological Review,* **69,** 306–328.

Bloomfield, T. M. (1969). Behavioural contrast and the peak shift. In R. M. Gilbert & N. S. Sutherland (Eds.), *Animal discrimination learning* (pp. 215–241). New York: Academic Press.

Brown, B. L., Hemmes, N. S., Coleman, D. A., Jr., Hassin, A., & Goldhammer, E. (1982). Specification of the stimulus-reinforcer relation in multiple schedules: Delay and probability of reinforcement. *Animal Learning & Behavior,* **10,** 365–376.

Capaldi, E. D., & Sheffer, J. D. (1992). Contrast and reinforcement in consumption. *Learning and Motivation,* **23,** 63–79.

Eisenberger, R., Frank, M., & Park, D. C. (1975). Incentive contrast of choice behavior. *Journal of Experimental Psychology: Animal Behavior Processes,* **1,** 346–354.

Flaherty, C. F. (1982). Incentive contrast: A review of behavioral changes following shifts in reward. *Animal Learning & Behavior,* **10,** 409–440.

Freeman, B. J. (1971). Behavioral contrast: Reinforcement frequency or response suppression? *Psychological Bulletin,* **75,** 347–356.

Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior,* **13,** 243–266.

Hinson, J. M., & Staddon, J. E. R. (1981). Some temporal properties of local contrast. *Behaviour Analysis Letters,* **1,** 275–281.

Leitenberg, H. (1966). Conditioned acceleration and conditioned suppression in pigeons. *Journal of the Experimental Analysis of Behavior,* **9,** 205–212.

Malone, J. C., Jr. (1976). Stimulus-specific contrast effects during operant discrimination learning. *Journal of the Experimental Analysis of Behavior,* **24,** 281–289.

Nevin, J. A. (1973). The maintenance of behavior. In J. A. Nevin & G. S. Reynolds (Eds.), *The study of behavior: Learning, motivation, emotion, and instinct* (pp. 200–236). Glenview, IL: Scott, Foresman.

Nevin, J. A., Smith, L. D., & Roberts, J. (1987). Does contingent reinforcement strengthen operant behavior? *Journal of the Experimental Analysis of Behavior,* **48,** 17–33.

Picker, M., & Poling, A. (1982). Choice as a dependent measure in autoshaping: Sensitivity to frequency and duration of food presentation. *Journal of the Experimental Analysis of Behavior,* **37,** 393–406.

Williams, B. A. (1977). Contrast effects in simultaneous discrimination learning. *Animal Learning & Behavior,* **5,** 47–50.

Williams, B. A. (1979). Contrast, component duration, and the following schedule of reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes,* **5,** 379–396.

Williams, B. A. (1981). The following schedule of reinforcement as a fundamental determinant of steady-state contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior,* **35,** 293–310.

Williams, B. A. (1983). Another look at contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior,* **39,** 345–384.

Williams, B. A. (1988). The effects of stimulus similarity on different types of behavioral contrast. *Animal Learning & Behavior,* **16,** 206–216.

Williams, B. A. (1989). Component duration effects in multiple schedules. *Animal Learning & Behavior,* **17,** 223–233.

Williams, B. A. (1990). Pavlovian contingencies and anticipatory contrast. *Animal Learning & Behavior,* **18,** 44–50.

Williams, B. A. (1991). Behavioral contrast and stimulus value. *Animal Learning & Behavior,* **19,** 337–344.

Williams, B. A., & Wixted, J. T. (1986). An equation for behavioral contrast. *Journal of the Experimental Analysis of Behavior,* **45,** 47–62.

Received November 25, 1991
Final acceptance April 16, 1992