Competing sources of stimulus value in anticipatory contrast

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In previous studies of anticipatory contrast, identical target components (A and B) preceded either a lower (extinction) or a richer schedule. Higher response rates occurred during the target preceding the lower rate of reinforcement, whereas preference was in favor of the target preceding the richer schedule. In Experiment 1, the response and preference measures were positively related when additional stimuli, with no reinforcement of their own, preceded the target components. The effect of these additional stimuli was presumed to be due to their overshadowing of the Pavlovian association between the target components and their following schedules. Experiment 2 also demonstrated a consistent relation between response rate and preference in a conditioned reinforcement procedure. In the absence of a strong Pavlovian association, anticipatory contrast, like other forms of contrast in free-operant procedures, reflects an increase in the value of the target component with an unchanged reinforcement schedule.

Behavioral contrast occurs when the rate of responding maintained in a target component with a constant rate of reinforcement is inversely related to the rate of reinforcement available in the surrounding schedules. Such effects have often been interpreted as reflecting the concept of relative value: The reinforcing effectiveness of the constant schedule is increased, or decreased, as a function of the context of reinforcement in which it occurs (e.g., Bloomfield, 1969).

When steady-state performance is maintained by a multiple schedule with more than two components, behavior in a given target component has been shown to be separately influenced by the rate of reinforcement in the preceding and following components (Williams, 1979, 1981; Williams & Wixted, 1986). Moreover, the reinforcement schedule in the component following the target component appears to be the dominant variable, at least with respect to steady-state response rate. Contrast effects owing to the preceding schedule of reinforcement and the following schedule of reinforcement also are differentially influenced by third variables, such as stimulus similarity (Williams, 1988) and the temporal duration of components (Williams, 1979, 1989).

Given the functional dissociation of the different sources of contrast, an important issue is whether all types of contrast can be explained in terms of the same theoretical framework. Considerable data now challenge the *relative value* interpretation with respect to the following schedule of reinforcement (subsequently referred to as *anticipatory contrast*). Williams (1991, 1992) presented subjects with a four-component multiple schedule in which two target

components with equal reinforcement schedules were followed by different components with either higher or lower rates of reinforcement. After obtaining the typical anticipatory contrast effect, the stimuli associated with the target components were presented together during probe tests. In both studies, the target component that preceded the richer following schedule was preferred, despite a higher rate of responding during training to the target component that preceded the lower-valued schedule. A similar dissociation between response rate and stimulus value was also shown by Nevin, Smith, and Roberts (1987), who used a similar four-component multiple schedule and resistance to change as an index of reinforcement value. They found that greater resistance to change occurred in a component followed by a rich schedule than in a component followed by extinction, despite response rates being in the opposite direction.

One interpretation of the dissociation between response rate and preference is that the anticipatory contrast effect with respect to response rate reflects not an increase in stimulus value, but instead some kind of general arousal effect (cf. Amsel & Roussel, 1952). Accordingly, the increased response rate preceding extinction is perhaps due to *anticipatory frustration* (see Leitenberg, 1966). But before rejecting relative value as the correct interpretation of behavioral contrast, it is important to examine more closely the determinants of performance in the anticipatory contrast procedure.

The finding that preference has been shown to be in favor of the target stimulus leading to a richer schedule is not surprising from the perspective of the Pavlovian contingencies embedded in the anticipatory contrast procedure. Any stimulus that predicts an increased reinforcement rate in the succeeding component of the schedule should presumably acquire conditioned value and, therefore, be increasingly preferred in a choice test over a stim-

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ulus without such a Pavlovian contingency. Several previous experiments have directly demonstrated the importance of these Pavlovian contingencies under two variations of the anticipatory contrast procedure. The strongest effects are seen when the schedules in the target components are extinction and the different following schedules are associated with the same discriminative stimulus (Brown, Hemmes, Coleman, Hassin, & Goldhammer, 1982; Williams, 1992, Experiment 1): The target stimulus preceding the food reinforcement schedule engenders a great deal of responding, whereas the target that precedes extinction does not. Pavlovian effects are also seen when the target components have food schedules of their own, but with their different following schedules associated with the same stimulus (Williams, 1979, Experiments 2 and 3; Williams, 1990), although these effects are often variable across individual subjects and disappear with continued training. In such procedures, the Pavlovian effect (a higher rate to the target component followed by the richer schedule) is replaced by the anticipatory contrast pattern of behavior (Williams, 1992, Experiment 1) when the different reinforcement schedules in the two following components are discriminated conditional on which target stimulus preceded their presentation.

Given that response rates in the target components are reversed in direction when the different following schedules are discriminated, a possible interpretation of the contrast effect is that it involves a comparison of the reinforcement rates in the target components with the reinforcement rates in their respective following components and that this comparison is independent of the Pavlovian contingency and competes with the Pavlovian contingency for expression in the different measures of behavior. For response rate during baseline training, the contrast effect seems dominant; for preference in the probe tests, the Pavlovian contingency seems dominant. However, both effects are likely playing a role in both measures of behavior.

For such an account to be convincing, it is necessary to demonstrate that the Pavlovian contingency has an effect separable from the comparison process that is assumed to underlie contrast and that both make independent contributions to stimulus value. Because the onset of a stimulus is maximally sensitive to conditioning owing to a Pavlovian contingency, the procedure used in the present study subdivided the stimuli in the target component into a two-segment chain. In our previous anticipatory contrast procedure, two equivalent target components (A and B) were followed by components differing in value (A–X and B–Y), where the value of X was low and the value of Y was high. The present procedure modified the target components so that components X and Y were each preceded by a two-component chain (A1–A2–X and B1–B2–Y). No reinforcement was presented during Components A1 and B1, but responding during them advanced the schedule to A2 and B2, which provided equivalent schedules of reinforcement. Thus, the Pavlovian contingency should be expected to be evident primarily for the initial link, whereas the comparison process underlying contrast should be most evident in the terminal link.

A subsidiary goal of Experiment 1 was to investigate the conditioned reinforcement properties of the target stimuli to provide yet a third measure of stimulus value. Given that response rate and preference have been inversely related in the previous A–X B–Y anticipatory contrast procedures, the use of a response contingency to advance from A1 to A2 and from B1 to B2 allows an assessment of the relative conditioned reinforcement value of A2 versus B2. At issue is how those conditioned reinforcement properties are related to response rate versus preference.

EXPERIMENT 1

Method

Subjects

The subjects were 6 adult White Carneau pigeons with prior experimental histories. They were maintained at approximately 85% of their free-feeding weights by grain obtained during experimental sessions and postsession feedings when necessary. The birds were housed in individual cages under a 12:12-h light:dark cycle, with water and grit freely available.

Apparatus

Six operant chambers (approximately 36 cm wide, 32 cm long, and 35 cm high) were used. Three translucent response keys, 2.5 cm in diameter, were mounted on the front intelligence panel 26 cm above the floor and 7.25 cm apart. 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 I-W miniature lamp, located 8.75 cm above the center response key, provided general chamber illumination. Directly below the center key and 9.5 cm above the floor was an opening (5.7 cm high $\times$ 5 cm wide) that provided access to a solenoid-operated grain hopper. When activated, the hopper was illuminated from above with white light by a 28-V I-W miniature lamp. A speaker mounted above the center of the ceiling provided continuous white noise throughout the experimental sessions. Experimental events were controlled by IBM-compatible computers and a custom-built interface. These were programmed using Borland's Turbo Pascal and were located in an adjacent room.

Procedure

The subjects were trained on a multiple schedule with chain schedules in each component. The components were arranged in two sequences, A1–A2–X and B1–B2–Y, as is shown in Figure 1. The two sequences alternated randomly, with the constraint that the same sequence could not be presented for more than four consecutive trials. Transition from Components A1 to A2 and B1 to B2 occurred according to a variable-interval (VI) 30-sec schedule (scheduled intervals ranged from 10 to 50 sec). When a transition occurred, the preceding stimulus was turned off, and the following stimulus was illuminated. The duration of Components A2 and B2 was 60 sec minus the scheduled VI duration of the preceding component, so that the combined scheduled duration of the first two components in each sequence was 60 sec. The duration of Components X and Y was always 60 sec.

Food was not available in the first component of each sequence (A1 and B1). In the second component of each sequence (A2 and B2), food was delivered according to a VI 120-sec schedule. The schedule of reinforcement was always extinction during Component X and VI 30 sec during Component Y. Thus, the programmed contingencies were identical for the two sequences, except for the schedule of reinforcement in the final components.

The stimuli presented during Components A1, A2, B1, and B2 were white, blue, green, and red keylights, which transilluminated the entire response key. The stimulus assignments for all components

Figure 1. Diagram of the experimental procedure. Six components were arranged in sequences of three stimuli. Food was never delivered in the presence of Components A1 and B1; transition to the next component was response dependent. A2 and B2 had equal food schedules, and their transition to X and Y was response independent. Food was delivered at a high rate in Y, but never in X.

were counterbalanced across birds. At the beginning of each target component (A1, A2, B1, and B2), side key location was semirandomly determined so that, for every four trials involving a particular component, the stimulus appeared twice on the left response key and twice on the right response key. The stimuli correlated with Components X and Y were white forms on the center response key (horizontal and vertical lines for 4 birds and a circle and X for 2 birds).

Baseline sessions continued for approximately 80 min and included 20 presentations of each component. After every 4th baseline training session, one probe session was conducted. Probe sessions were similar to baseline training sessions, except that one probe trial followed every block of four training trials (each trial consisted of one three-component sequence). The normal contingencies were in effect for training trials, but reinforcement was not available during probe trials. Each probe trial consisted of two stimuli simultaneously presented on the side keys for 60 sec. Half of the probe trials involved the stimuli correlated with the first component of each sequence (A1 and B1), and half involved the stimuli correlated with the second component of each sequence (A2 and B2). Each type of probe trial was presented a total of four times, and the order in which the two types of probe trials were presented was randomly varied. Each probe stimulus was presented on the left key on half of the trials and on the right key on half of the trials. Also, half of the trials involving each type of probe trial followed Component X, and half followed Component Y. A total of 30 sessions were conducted.

Results

After the first block of five sessions, response rates for 5 of 6 subjects were higher during Component B1, which was the first segment in the sequence leading to the rich (VI 30-sec) food schedule. The mean rates of responding from the last five sessions were 33 and 39 responses per minute for Components A1 and B1, respectively. The results for individual subjects are shown in Table 1.

Table 1 also shows comparable data during the second component (A2 and B2) of each sequence. In these components, the rates of responding were consistent with a typical anticipatory contrast effect, in that all 6 birds generally showed higher rates of responding to the component followed by extinction. It is also opposite in direction to the pattern of responding observed in the first component of each sequence. The mean rates of responding from the

last five sessions were 94 for Component A2 and 65 for Component B2.

The rightmost columns of Table 1 show the choice proportions from the last two probe sessions. The average pattern of preference observed in each type of probe trial was consistent with the response rates to the individual components during training. Five of the 6 birds preferred Component B1 over Component A1 (mean preference for A1 was .32). Five of the 6 subjects preferred Component A2 over Component B2 (mean preference for A2 was .67). As with the response rate data from baseline training, the pattern of responding during probe tests involving A1 and B1 was opposite in direction to the pattern obtained with A2 and B2.

As was expected, response rates in Components X and Y reflected the difference in rate of reinforcement and, therefore, will not be discussed.

Discussion

The results of Experiment 1 were consistent with previous reports of anticipatory contrast in that the component immediately preceding extinction maintained a higher level of responding than did the component immediately preceding a rich schedule of reinforcement (cf. Williams, 1981, 1991, 1992). However, preferences on probe trials

Table 1
Results of Experiment 1

Bird	Responses per Minute				Choice Proportions	
	A1	A2	B1	B2	A1 (vs. B1)	A2 (vs. B2)
T0	23	57	28	59	.48	.97
T1	41	105	46	60	.21	.55
T2	18	153	30	95	.51	.61
T3	50	104	57	77	.44	.11
B0	29	72	28	53	.21	.99
B2	40	71	44	46	.06	.76
Mean	33	94	39	65	.32	.67

Note—Responses per minute are averaged from the last five sessions. Choice proportions are from the last two probe sessions.

involving simultaneous presentation of these stimuli (A2 and B2) were inconsistent with the results of previous studies. Williams (1991, 1992) found that response rate measures during training were inversely related to preference tests, whereas the present study found a positive relation between the two measures. That is, A2 was preferred over B2 and also had a higher response rate.

Although there were numerous procedural differences (e.g., component durations) between Experiment 1 and previous studies (Williams, 1991, 1992) that might be relevant to their different outcomes, the most likely reason that response rate and preference for A2 versus B2 were positively related in the present study is that they were preceded by A1 and B1, respectively. This allowed the initial-link stimuli to predict the schedules during X and Y, so that A2 and B2 were redundant as predictors. Accordingly, the Pavlovian association between B2 and the rich schedule during Y would be attenuated. This should decrease the value of B2, which in turn reversed the outcome of the A2 versus B2 preference test. The relatively greater preference for A2 presumably reflected the effect of anticipatory contrast on its relative value.

The relation between response rate and preference for A1 versus B1 supports this interpretation. Both measures were in favor of B1, despite the fact that both response rate and preference favored A2 over B2. The inverse relation between the first and the second segments of the chain schedules is the reverse of what should be expected on the basis of the conditioned reinforcement properties of A2 versus B2, because conditioned reinforcement presumably requires the higher value terminal link to maintain a higher rate in its corresponding initial link. Given the opposite finding, the most plausible explanation is that behavior in A1 and B1 were controlled by their relations to X and Y, rather than by their relations to A2 and B2.

EXPERIMENT 2

Experiment 2 had three goals. The first was to establish that previous results with the four-component A–X B–Y multiple schedules, where preference and response rate were inversely related, could be replicated using the same experimental setup as that in Experiment 1. If so, this would establish that the positive relation between response rate and preference found in Experiment 1 was due to the initial links of the chain schedules.

The second goal of Experiment 2 was to determine whether the higher response rate and preference for B1 over A1 was in fact due to their Pavlovian associations with respect to X and Y, rather than the conditioned reinforcement contingencies with respect to A2 and B2. After initial training with the four-component A–X B–Y schedules, training with chains A1–A2 and B1–B2 were interspersed on separate trials. A1 and B1, therefore, never directly predicted X and Y, so that responding during them would be due entirely to the conditioned reinforcement properties of A2 and B2. At issue is how the pattern of response rate and preference for A1 versus B1 would be changed from that obtained in Experiment 1.

The third goal of Experiment 2 was to determine whether the conditioned reinforcement properties of A2 and B2 are correlated with preference or response rate. Assuming that A1 and B1 response rate and preference track the conditioned reinforcement value of A2 and B2 and that preference and response rate are inversely related for those stimuli, it should be possible to determine which measure is the major determinant of stimulus value. As will be seen, the relative importance of the two variables varied across individual subjects.

Method

Subjects and Apparatus

Six White Carneau pigeons were maintained as described in Experiment 1. These subjects had previous experience in an unrelated procedure. The apparatus and stimuli were the same as those in Experiment 1.

Procedure

Phase 1. The initial procedure consisted of 2 two-component sequences, as is shown in Figure 2. Components A2 and B2 provided food according to VI 120-sec schedules. Transition to the following schedule occurred according to a variable-time 30-sec schedule. A2 was followed by Component X, which never provided food. B2 was followed by Component Y, which provided food according to a VI 30-sec schedule. The duration of X and Y was always 60 sec. Within each block of four trials (a trial consisted of a single two-component sequence), each type of trial occurred twice, and the order in which each trial was presented was randomly determined. Unreinforced probe trials were presented every 5th session, as described in Experiment 1. Phase 1 continued for a total of 40 sessions.

Phase 2. Following the initial phase of training, two additional types of trials were added to the procedure. As is shown in Figure 2, A1 and B1 preceded A2 and B2, respectively. No food was presented during A1 and B1, and transition to their following components occurred according to a VI 30-sec schedule. Each of the four trial types was presented equally often. Because A2 and B2 were each presented in two of the sequences, they occurred twice as often as the other components. Each trial type occurred once in each block of four consecutive trials, but the order in which the trials were presented was randomly determined. Phase 2 continued for a total of 25 sessions.

Results

Phase 1

During Phase 1 training, all of the subjects except T21 showed higher rates of responding to the component preceding extinction (A2), replicating the finding of anticipatory contrast. During the last block of Phase 1, the mean rates of responding to A2 and B2 were 70 and 49, respectively. Preference obtained from the last two probe sessions of Phase 1 was in favor of component B2 for 5 of the 6 birds (mean choice proportion for A2 = .33). Results for individual subjects are shown in Table 2. These findings replicate the previous reports of an inverse relation between response rates and preference in anticipatory contrast procedures (Williams, 1991, 1992).

Phase 2

Table 3 shows response rates during Phase 2. The relative rate of responding to A2 and B2 remained virtually unchanged from Phase 1, although every bird showed an elevation in the absolute rate of responding to these com-

Figure 2. Diagram of the procedure used in Experiment 2. The Phase 1 procedure consisted of two sequences of components, and the Phase 2 procedure consisted of four sequences of components. Food was never delivered in the presence of Components A1 and B1, and transitions to A2 and B2 were response dependent. A2 and B2 provided equal rates of food. Food was delivered at a high rate in Y, but never in X.

ponents. The mean rates of responding during the last block of training were 91 and 64 responses per minute to A2 and B2, respectively. The overall preference for B2 was similar to that in Phase 1 (mean choice proportion for A2 = .31).

Responding during Components A1 and B1 was inconsistent across subjects. During the first block of training, 2 birds showed higher rates of responding to A1, 2 birds showed roughly equivalent rates of responding to A1 and B1, and 2 birds showed higher rates of responding to B1. Although the mean relative rate of responding was close to .50 during both the beginning and the end of Phase 2, the variance decreased as training continued.

As is shown in Figure 3, all the subjects maintained substantial rates of responding in Components A1 and B1, despite the absence of food delivery within those components. Although response rates in A1 and B1 tended to converge, total response rates remained stable for most subjects. The mean rates of responding to A1 and B1 during the last block of training were 41 and 48 responses per minute, respectively.

Preference between A1 and B1 also varied across subjects. Three birds showed preference for A1, and 3 birds showed preference for B1. As is shown in Figure 4, preference on the probe tests varied over training, although most subjects were generally consistent with respect to their preferred stimulus. The mean choice proportion for A1 over the last two probe sessions was .48. Data for individual subjects during the last two probes are shown in Table 3.

Although the mean relative response rates and preference for A1 versus B1 were near indifference, performance

for A1 versus B1 was consistent for individual subjects. That is, some subjects had a higher response rate and preference for A1, whereas others had a higher response rate and preference for B1, but for a given subject response rate and preference were consistent with respect to the higher valued stimulus. Comparison of Figures 3 and 4 shows the relation between absolute response rates and preference during the probe tests throughout the 25 sessions of Phase 2 training. Although there are fluctuations in both measures at various points in training, the two measures were generally consistent.

The consistency between preference and relative response rate measures for initial-link responding, seen by comparing Figures 3 and 4, is further supported by the correlational analysis presented in Table 4. Measures 1 and 2 correspond to the A2 and B2 terminal links during the last five sessions of Phase 1, whereas measures 3 and 4 correspond to the A1 and B1 initial links during the first five

Table 2
Results of Phase 1 of Experiment 2

Bird	Responses per Minute		Choice Proportions: A2 (vs. B2)
	A2	B2	
T21	60	59	.19
T22	52	39	.45
T23	38	33	.55
T24	172	93	.08
B21	49	34	.39
B22	49	35	.32
Mean	70	49	.33

Note—Responses per minute are averaged from the last five sessions of training. Choice proportions are averaged from the last two probe sessions.

Table 3
Results of Phase 2 of Experiment 2

Bird	Responses per Minute				Choice Proportions	
	A1	A2	B1	B2	A1 (vs. B1)	A2 (vs. B2)
T21	38	75	55	79	.21	.05
T22	41	77	41	47	.73	.31
T23	50	69	29	55	.96	.31
T24	58	205	102	114	.02	.25
B21	33	64	30	43	.90	.50
B22	24	57	32	44	.08	.42
Mean	41	91	48	64	.48	.31

Note—Responses per minute are averaged from the last five sessions of training. Choice proportions are averaged from the last two probe sessions.

sessions of Phase 2. For the initial-link behavior, there was a very high correlation between relative response rate and preference ($r = .93$), consistent with the similarities seen between Figures 3 and 4. For the terminal-link behavior at the end of Phase 1, there was a moderate but nonsignificant negative correlation ($r = -.40$) between relative response rate and preference, consistent with previous findings of an inverse relation between the two measures of value (e.g., Williams, 1992). Both measures of initial-link stimulus value were highly correlated with the preference between the terminal links ($r = .89$ and $.93$ for response rate and preference, respectively). Both measures of initial-link stimulus value had small nonsignificant negative correlations with terminal-link relative response rate, but this was at least partially forced statistically by the fact that relative response rate and preference for the terminal links were themselves negatively correlated.

Measures 5–8 of Table 4 correspond to the last five sessions of training of Phase 2. Response rate and preference for the initial links continued to be highly correlated ($r = .91$), and both measures continued to be highly correlated with the preference between the terminal links at the end of Phase 1 ($r = .94$ and $.86$ for response rate and preference, respectively). However, neither measure was significantly correlated with either measure of terminal-link value during the last five sessions of Phase 2. In part, this was due to a change in the pattern of correlation between response rate and preference for the terminal links during the last five sessions of Phase 2. It should be noted that nonsignificant correlations have little meaning, given the small number of subjects on which the correlational analysis was conducted.

The procedure used in phase two involved four trial types (A2–X, B2–Y, A1–A2, and B1–B2). Because Components A2 and B2 were each presented during two different types of trials, responding during these components was recorded separately, depending on the trial type. In both cases, responding was higher when the components followed A1 or B1 than when they preceded X or Y. Also, response rate was higher to A2 than to B2 in both sequential locations.

Discussion

Experiment 2 showed overall greater responding to a target component immediately preceding extinction, as compared with an equivalent target preceding a rich schedule of reinforcement, replicating previous reports of anticipatory contrast. More important, probe trials revealed pref-

Figure 3. Response rates to the initial-link stimuli during Phase 2 of Experiment 2.

Figure 4. Preference between the initial-link stimuli on the probe tests presented in Phase 2 of Experiment 2.

erence for the target component preceding the rich schedule of reinforcement. This preference was evident in earlier studies (e.g., Williams, 1991, 1992) but was not observed with the procedure used in Experiment 1, in which the target components consisted of two-link chain schedules. These results provide support for the notion that the inclusion of Components A1 and B1 in Experiment 1 altered the stimulus function of Components A2 and B2. Specifically, Component B1 is hypothesized to have usurped the predictive role normally provided by B2 in

relation to the rich Component Y. Component B1 was the first stimulus with a predictive relationship to Component Y and presumably acquired value from this relationship. Conversely, Component B2 may have lost value owing to the presence of B1. Because Components A1 and B1 were absent in Phase 1 of Experiment 2, preference for Component B2 was similar to levels reported in previous studies. Phase 2 provided a new opportunity to address the relative value of Components A2 and B2. Given the dissociation between relative response rate and preference for

Table 4
Correlations Between Relative Rates of Responding and Preference

Measure	1	2	3	4	5	6	7	8
1. Response rate: A2/(A2+B2), Phase 1, Sessions 35–40	—	-.40	-.34	-.16	-.42	-.30	.87*	.46
2. Choice proportion: A2/(A2+B2), Phase 1, Sessions 35–40		—	.89*	.93†	.94†	.86*	-.01	.46
3. Response rate: A1/(A1+B1), Phase 2, Sessions 1–5			—	.93†	.73	.72	.12	.28
4. Choice proportion: A1/(A1+B1), Sessions 1–5				—	.82*	.87*	.29	.55
5. Response rate: A1/(A1+B1), Phase 2, Sessions 21–25					—	.91*	-.06	.36
6. Choice proportion: A1/(A1+B1), Sessions 21–25						—	.12	.41
7. Response rate: A2/(A2+B2), Phase 2, Sessions 21–25							—	.51
8. Choice proportion: A2/(A2+B2), Phase 2, Sessions 21–25								—

Note—Response rate data are averages of five sessions. Choice proportions are averages from two probe sessions. * $p < .05$. † $p < .01$.

A2 versus B2 in Phase 1, their abilities to serve as conditioned reinforcers for A1 versus B1, respectively, should provide a third measure of stimulus value. No food was available for responding to A1 or B1, but responses were reinforced by transition to A2 or B2. Unlike Experiment 1, here, A1 and B1 were never predictive of X and Y at the end of the stimulus sequence and could not, therefore, acquire value from direct associations with X and Y. Thus, the relative value of A1 versus B1, whether measured in terms of relative response rate or preference, should reflect the relative value of A2 versus B2.

Given that response rate and preference for A2 versus B2 were inversely related in Phase 1 of Experiment 2, a possible outcome could have been that contrast and preference would be inversely related for A1 versus B1 as well. The results were surprising. Individual subjects differed in their response patterns to Components A1 and B1. Some subjects showed a clear preference and higher response rate for A1; some showed a clear preference and higher response rate for B1. All the subjects showed consistent relations between the response rate and the preference measures regardless of which of the initial-link stimuli was preferred. Because of the consistency between the two measures, a plausible interpretation is that the relative value for A2 versus B2 differed for individual subjects, with the degree of anticipatory contrast more strongly determining value for some subjects, whereas preference, which presumably reflects the Pavlovian contingency, more greatly determined value for other subjects. The correlational pattern seen in Table 4 suggests that preference between the terminal-link stimuli was a stronger predictor of the value of the initial-link stimuli than was the degree of anticipatory contrast with respect to the terminal links, but such correlations with a small number of subjects are difficult to interpret, because of differences in reliability of the different variables.

An alternative interpretation of the consistent relation within individual subjects between preference and response rate for A1 versus B1 is simple stimulus bias. Given that the different subjects received different stimulus assignments for the purposes of counterbalancing, if one of the stimuli were highly preferred, this would produce a bias either in favor of or against that stimulus for both the preference and the response rate measures, thus producing the patterns of results seen in Figures 3 and 4. Contrary to that interpretation, however, was the finding that both measures were strongly predicted by the preference for A2 versus B2 at the end of Phase 1 training. If the consistent relation between response rate and preference for A1 versus B1 were due simply to stimulus preference, neither measure should have been strongly correlated with preference for A2 versus B2.

The most important finding in Experiment 2 was the consistent relation between the degree of contrast and preference for the initial-link stimuli. Along with the consistent relations found in both the initial and the terminal links of the chain target components in Experiment 1, the paradox from previous studies showing a dissociation between response rate and choice as measures of value seems to

be resolved. Both changes in response rate owing to anticipatory contrast and changes in preference owing to the embedded Pavlovian contingencies appear to make independent contributions to the stimulus value of the target components, however that value is measured. In previous studies, these separate contributors to value were negatively correlated because the same stimulus that predicted the rich following schedule was also the stimulus that should have had its response rate suppressed because of anticipatory contrast. Conversely, the stimulus that should have had its response rate increased because of anticipatory positive contrast was the stimulus that had had a Pavlovian association with extinction as the following schedule. In the present experiments, on the other hand, these two types of contingencies were no longer inversely correlated. In Experiment 1, this was accomplished by degrading the Pavlovian predictive relation between the A2 versus B2 terminal links and their respective following schedules by adding the initial-link stimuli that apparently overshadowed the terminal links as predictors of the schedule at the end of the stimulus sequence. In Experiment 2, this was accomplished by having the initial links of the chain schedule never occur on the same trial sequence as did X and Y, which meant that a Pavlovian relationship between the initial-link stimuli and the X and Y following schedules was never in effect. In both cases, the attenuation of the Pavlovian contingency caused preference and response rate to become highly positively correlated.

A complete dissociation of the effects of the Pavlovian contingency from those of the dynamics of contrast would ideally entail a parametric manipulation of the variables that separately control each. For example, greater stimulus similarity between the target component stimuli and their respective following components should increase the effect of the Pavlovian contingency and decrease the amount of anticipatory contrast (cf. Rescorla & Furrow, 1977; Williams, 1988). Such a manipulation should then increase preference for all subjects in the present procedure in favor of B2 and also, therefore, increase preference for B1 over A1. It should also be possible to identify other experimental variables that would accomplish a similar dissociation (e.g., the use of an intertrial interval separating each component sequence).

The hypothesis that anticipatory contrast procedures may produce a contest between contrast effects and the effects of the embedded Pavlovian contingencies offers some possible insight into the understanding of anticipatory contrast obtained in consummatory licking experiments. Flaherty (1996) has reviewed an extensive series of experiments in which rats lick a drinking tube containing a saccharin solution for a period of minutes, which is then followed by a second drinking tube that either contains more of the same saccharin solution or some highly preferred solution (e.g., sucrose). Licking rate to the first drinking tube is substantially suppressed when the second drinking tube contains a higher valued solution.

When the target solution is cued by a distinctive flavor, anticipatory contrast is not obtained (Flaherty, Coppotelli, Grigson, Mitchell, & Flaherty, 1995; Lucas & Timberlake,

1992). Moreover, when rats are given a preference test between the different flavors, a strong preference occurs in favor of the flavor that leads to the preferred following solution. These differences between environmental versus taste cues are most readily understood in terms of the preferential Pavlovian associations between tastes and food. Because of the "prepared" nature of those associations, Pavlovian conditioning rapidly occurs when the target solution is cued by a taste, which increases the preference for that solution and overwhelms the contrast effect that normally occurs when environmental cues predict the richer following schedule. Support for this interpretation comes from within-subjects experiments in which the different following solutions were cued by different types of drinking spouts (Flaherty et al., 1995, Experiments 9a and 9b). Here, anticipatory contrast occurred, and no preference was evident for the drinking tube that cued the following sucrose solution. This change in outcome from that obtained with taste cues presumably reflects a decreased role of the Pavlovian associations. Possibly, therefore, if the Pavlovian association were attenuated yet more by experimental manipulations like those used in Experiment 2 of the present study, not only would anticipatory contrast occur, but differential preference for the cue associated with contrast might be demonstrable as well.

The major theoretical implication of the present study is that the changes in response rate owing to anticipatory contrast correspond to changes in stimulus value. Thus, all forms of contrast appear to support an interpretation of contrast in terms of relative value. As was argued in the early investigations of contrast, a given reinforcement schedule has lesser or greater reinforcement effectiveness, depending on the richness of the context of reinforcement in which it occurs.

A theoretical paradox nevertheless remains. In order for anticipatory contrast to occur in the four-component A-X, B-Y procedure, the A and B stimuli must differentially predict the occurrence of X and Y. In Experiment 1, this meant that A2 and B2 also had to predict X and Y. Yet when these stimuli were made redundant by the addition of A1 and B1, as initial links, the assumption was that the associations between the terminal links and X and Y were reduced. The issue is why the addition of the initial links should decrease the Pavlovian association of A2 and B2 with X and Y, respectively, but leave intact the relation between the terminal links and their respective following schedules that causes anticipatory contrast to occur. Is this latter type of stimulus relation of a different type than

a simple Pavlovian association, and if so, how should it be characterized?

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