

*BEHAVIORAL CONTRAST IN COMPETITIVE AND
NONCOMPETITIVE ENVIRONMENTS*

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Three experiments examined the effects of opportunities for an alternative response (drinking) on positive behavioral contrast of rats' food-reinforced bar pressing. In both Experiments 1 and 2 the baseline multiple variable-interval schedules were rich (variable interval 10-s), and contrast was examined both with and without a water bottle present. In Experiment 1, the rats were not water deprived. When one component of the multiple schedule was changed to extinction, the rate of bar pressing increased in the constant component (positive behavioral contrast). The magnitude of contrast was larger when the bottle was absent than when it was present, as predicted by the matching law. Drinking did not shift from the constant variable-interval component to the extinction component, as might have been expected from competition theory. In Experiment 2, the rats were water deprived. Contrast was larger when the bottle was present than when it was absent, and drinking did shift to the extinction component, as predicted by competition theory. In Experiment 3, water-deprived rats responded on leaner multiple variable-interval schedules (60-s) in the presence of a water bottle. When one component was changed to extinction, contrast did not occur, and drinking did not shift to the extinction component. The present results suggest that there are at least two different sources of behavioral contrast: "competitive" contrast, observed when an alternative response occurs with high probability, and "noncompetitive" contrast, observed when an alternative response occurs with low probability. The results, in conjunction with earlier studies, also suggest that the form of the alternative response and the rate of food reinforcement provided by the multiple schedule combine to determine the amount of contrast.

Key words: behavioral contrast, behavioral competition, matching theory, multiple schedules, bar pressing, rats

A reinforced response tends to occur at a rate inversely proportional to the rate of reinforcement provided by other sources. Behavioral contrast in multiple schedules (Reynolds, 1961) is perhaps the best example of this effect. When the rate of reinforcement in one component of a multiple schedule is decreased, the response rate in the other, constant component increases (positive behavioral contrast). When the rate of reinforcement in one component of a multiple schedule is increased, the rate of responding in the constant component decreases (negative behavioral contrast).

Several theories have been proposed to account for contrast (see Williams, 1983, for review). The present paper will focus on two current theories of behavioral contrast: matching (Herrnstein, 1970; Williams, 1983) and competition theory (Ettinger & Staddon, 1982; Hinson & Staddon, 1978; Staddon, 1982). A third theory, additive theory (Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973), makes no obvious predictions about the conditions reported here and will not be considered.

Matching theory describes behavioral contrast with Herrnstein's (1970) equation (Equation 1) or with related forms (Williams, 1983; Williams & Wixted, 1986).

$$P = \frac{kr_1}{r_1 + mr_2 + r_0} \quad (1)$$

In Equation 1, P represents the response rate during one component of a multiple schedule, and r_1 represents the reinforcement rate for that response. The reinforcement rate during the other component is represented by r_2 . The

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three free parameters, k , m , and r_0 , represent the asymptotic rate of P , the degree of interaction between components, and the reinforcement rate from unscheduled sources, respectively. When both components provide reinforcement (i.e., both r_1 and $r_2 > 0$), changes in r_2 will cause P to change in the opposite direction. This, by definition, is behavioral contrast.

According to competition theory (Ettinger & Staddon, 1982; Hinson & Staddon, 1978; Staddon, 1982), two different classes of behavior compete for available time. One class, terminal behavior, is directly controlled by scheduled reinforcement. The other class, interim behavior, occurs when terminal responses are not occurring. When the reinforcement rate during one component of a multiple schedule is decreased, terminal responding during that component decreases because terminal responding is controlled by its reinforcement rate. Assuming that the total amount of interim behavior (and reinforcement for interim behavior) remains constant, this decrease in terminal responding in the changed component allows some interim responses that had been occurring during the other, constant component to shift to the changed component. The reallocation of interim responses from the constant component, in turn, allows terminal responding to increase in the constant component because of decreased competition (disinhibition). The increase in terminal responding in the constant component is, by definition, positive behavioral contrast.

Competition theory predicts that the magnitude of increase in terminal responding in the constant component will be determined by the proportion of the constant component taken up by interim responding during baseline. This is so because terminal responding in the constant component can increase only to the degree that interim responding has decreased in that component. Assuming that interim responding takes up no more than half of the total session time, and assuming that interim responding is equally distributed between components during baseline conditions, this relationship is described by Equation 2 (from Staddon, 1982).¹

$$C_0 = \frac{R_x + 0.5R_z}{R_x} \quad (2)$$

In Equation 2, C_0 is the maximum possible magnitude of positive behavioral contrast, expressed as the response rate in the constant component during a contrast phase divided by the response rate in that component during precontrast (baseline) schedules. It is the magnitude that would be expected if all interim behavior shifted to the extinction component. R_x is the rate of reinforcement provided for the instrumental (terminal) response in the constant component, and R_z is the total rate of reinforcement for alternative (interim) responses in both components and is assumed to determine the amount of interim behavior. R_z is multiplied by 0.5 because only half of the total interim responses are assumed to occur in the constant component during baseline. The term R_z , then, correlates with the amount of interim behavior that can be reallocated from the constant component to the extinction component, assuming that the total amount of interim behavior remains constant.

Examination of Equations 1 and 2 shows that matching theory and competition theory make different predictions about the effects of reinforcement of alternative responses that are incompatible with the instrumental response. According to matching theory (Equation 1), the presence of an alternative source of reinforcement will decrease the magnitude of behavioral contrast. Alternative reinforcers should increase the size of r_0 . Because r_0 is in the denominator of Equation 1, increases in r_0 attenuate the change in P resulting from a change in r_2 .

Competition theory (Equation 2) makes the opposite prediction. The addition of an alternative source of reinforcement should increase the size of R_z . Because R_z is in the numerator of Equation 2, any increase in the size of R_z should increase the size of C_0 .

In the one experiment directly testing the effect of an alternative response on behavioral contrast, Hinson and Staddon (1978) found more contrast when rats' food-reinforced bar pressing was accompanied by concurrent ac-

ules. The second equation describes contrast in situations in which the alternative activity takes up more than half of the total session time. Because these conditions did not occur in the present experiments, the second equation is not considered here.

¹ Equation 2 is one of two equations proposed by Staddon (1982) to describe positive contrast in multiple sched-

cess to a running wheel than when the wheel was not accessible. This result supports competition theory and Equation 2. In addition, wheel running was differentially allocated to the component providing the lower rate of reinforcement, as predicted by competition theory.

Competition theory, however, cannot provide a complete account of all instances of contrast. Recently, Dougan, McSweeney, and Farmer (1985) examined behavioral contrast and interim behavior allocation in rats, using two different reinforcement rates and two different component durations. Although contrast was found when the instrumental response was reinforced at high rates, interim behavior (water drinking) was not differentially allocated to the component providing the lower rate of reinforcement, a result contrary to competition theory.

The Dougan et al. (1985) study, however, did not provide a strong test for the differences between competition and matching theories. Such a test would be an examination of the magnitude of behavioral contrast in the presence and absence of an alternative drinking response, under the same schedule parameters used in the Dougan et al. study. This test was conducted in Experiment 1 of the present paper. During baseline conditions, rats' bar pressing produced food on schedules that provided high baseline rates of reinforcement—multiple variable-interval 10-s variable-interval 10-s (VI 10-s VI 10-s)—in either the presence or absence of free water. If competition theory is correct, the magnitude of subsequent contrast should be greater when water is available than when it is not. If matching theory is correct, contrast should be greater when water is not available than when it is available.

EXPERIMENT 1

METHOD

Subjects

The subjects were 5 Sprague-Dawley rats from the breeding colony at the Washington State University Psychology Department. One rat died during the course of the experiment, leaving a total of 4. All rats had extensive experimental histories of food-reinforced responding on multiple schedules similar to those used in the present study. Each rat was housed

individually and was maintained at approximately 80% of its free-feeding weight. Water was freely available in the home cage throughout the experiment.

Apparatus

The apparatus was a standard conditioning chamber for rats, 24 cm by 30 cm by 19 cm. Three 5-W lights were spaced evenly in the front wall, 15 cm from the floor. Each side light was 10 cm from the center light and 5 cm from the closest wall. During the experiment, the left (red) light served as a discriminative stimulus and the center (white) light provided chamber illumination.

The lower left corner of the front wall contained a food cup, 4 cm from the left wall and 4 cm from the floor. A response bar was positioned immediately above the food cup, 6 cm from the left wall and 10 cm from the floor. A force of approximately 0.3 N, applied to the center of the bar, was required to operate the bar.

A water bottle, 4 cm in diameter, was mounted in the right wall of the chamber, 12 cm from the center of the response bar. A spring-mount allowed the water bottle to be easily removed from the chamber. Contact with the tip of the drinking tube activated a low-current electrical (lickometer) circuit. The entire apparatus was housed in a sound-attenuating chamber, with an exhaust fan masking sounds from the electromechanical programming equipment.

Procedure

All subjects had previous histories of food-reinforced bar pressing on multiple schedules, so no shaping was necessary. The subjects were exposed to a series of multiple schedules in the order outlined in Table 1. Each rat received two identical three-schedule series, one with the water bottle present and one with the water bottle absent. Each series consisted of an initial multiple VI 10-s VI 10-s schedule. This was followed by a multiple VI 10-s extinction schedule (VI 10-s EXT). Finally, another multiple VI 10-s VI 10-s schedule was presented. Components of the multiple schedule alternated every 90 s. One component was accompanied by the presence of the red light; the other was accompanied by the absence of the red light. When the components provided different reinforcement rates,

Table 1

Outline of experimental procedures for Experiments 1 and 2.

Schedule	Reinforcers per session
Water bottle present	
Multiple VI 10-s VI 10-s	120
Multiple VI 10-s EXT	60
Multiple VI 10-s VI 10-s	120
Water bottle absent	
Multiple VI 10-s VI 10-s	120
Multiple VI 10-s EXT	60
Multiple VI 10-s VI 10-s	120

the red light was on during the VI component and off during the EXT component. Reinforcers were single 45-mg Noyes pellets. Intervals of the VI schedule were calculated using the method suggested by Catania and Reynolds (1968, Appendix 2).

Sessions were conducted 6 or 7 days per week and were terminated when a fixed number of reinforcers had been delivered. This number was varied across schedules in order to keep session time roughly constant. Each schedule was in effect for 15 sessions.

RESULTS

Absolute rates of bar pressing were calculated by dividing the number of presses during a component by the number of minutes spent in that component. Table 2 shows the mean rates of bar pressing during the constant (red light) and the changed (no light) components computed over the 15 sessions of each schedule. Positive behavioral contrast is indicated by a higher rate of responding in the constant (VI 10-s) component of the multiple VI 10-s EXT schedule than in the same component of the preceding and subsequent multiple VI 10-s VI 10-s schedules. As seen in Table 2, only Rat 105 in the bottle-present condition failed to show behavioral contrast.

The magnitude of contrast was estimated by dividing the mean rate of responding during the constant component of multiple VI EXT by the mean rate of responding during the constant component of the two multiple VI 10-s VI 10-s baseline schedules, multiplying by 100, and subtracting 100 from the result. This yields a percentage deviation from baseline, with a positive score indicating positive behavioral contrast. The magnitude of

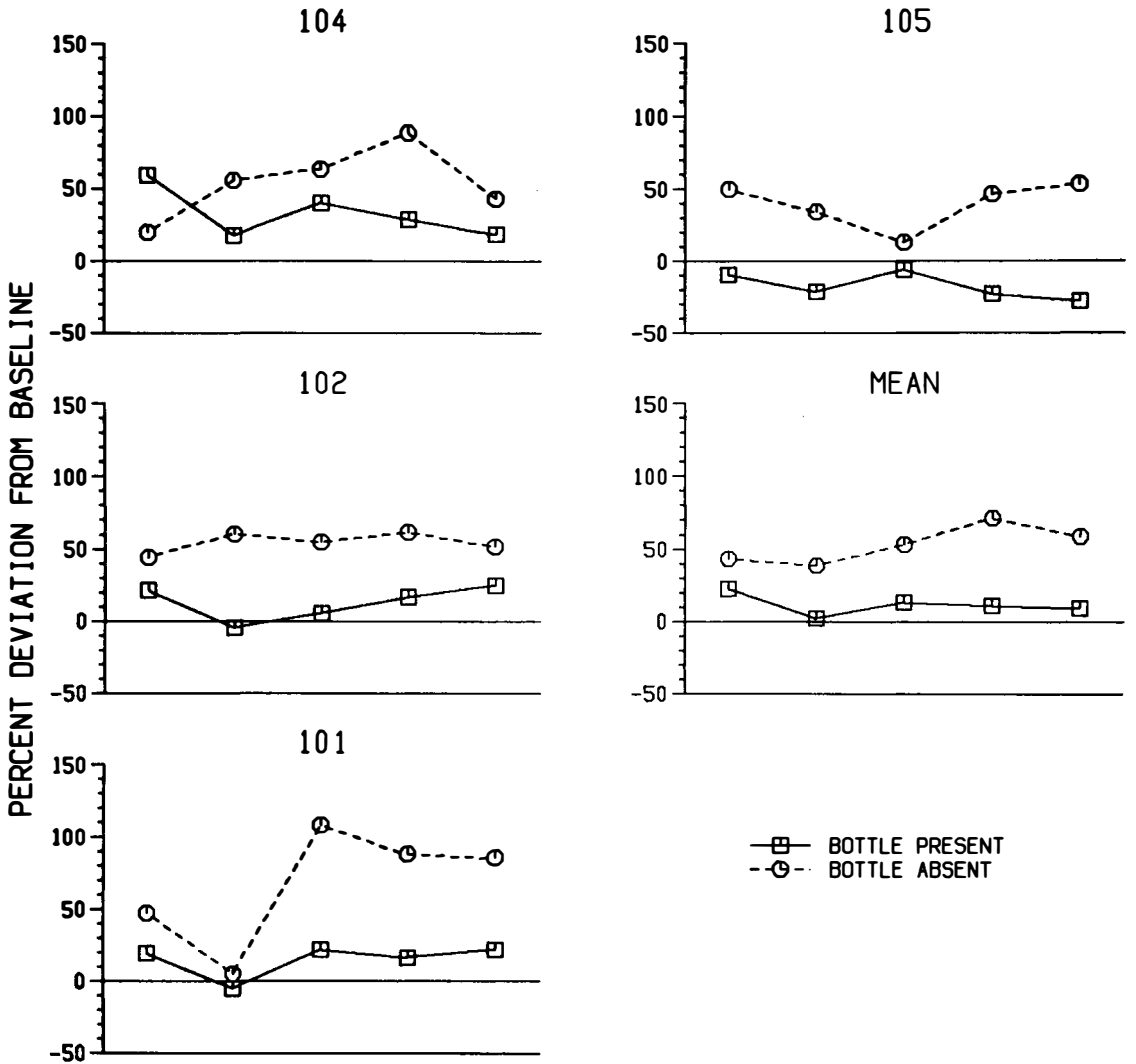
Table 2

Mean bar presses per minute during the constant (red light) component and during the changed (no light) component, for all animals on all schedules in Experiment 1.

Subject	Component	Schedule		
		VI 10-s VI 10-s	VI 10-s EXT	VI 10-s VI 10-s
Bottle present				
101	Constant	50.8	51.1	38.0
	Changed	48.4	24.1	38.6
102	Constant	40.3	42.9	36.0
	Changed	39.3	14.1	34.9
104	Constant	27.4	36.9	28.0
	Changed	27.5	19.3	26.5
105	Constant	32.0	29.3	40.8
	Changed	27.1	16.8	41.3
Bottle absent				
101	Constant	40.3	54.2	21.2
	Changed	40.7	6.9	20.0
102	Constant	39.7	61.4	39.4
	Changed	47.1	14.2	41.4
104	Constant	29.9	41.9	24.4
	Changed	29.7	10.9	22.9
105	Constant	47.9	53.2	32.5
	Changed	49.3	12.2	29.6

contrast in both the bottle-present and the bottle-absent conditions is presented in Figure 1 as three-session means for each subject. The magnitude of contrast was greater when the bottle was absent (overall mean of 54.5%) than when it was present (overall mean of 9.8%) for each subject in the experiment. A two-tailed *t* test for repeated measures showed these differences to be significant, $t(3) = 5.45$; $p < .02$. (Although order was confounded with bottle presentation, the pattern of results between Experiments 1 and 2 suggests that order was not responsible for the differences in contrast.)

Figure 2 presents the mean rates of licking in both the constant (unshaded bar) and changed (shaded bar) components during each of the three schedules of the bottle-present condition. The height of each bar is the sum of the licking rates in both components. Note the use of different scales with different animals. The figure shows that for 3 of the 4 rats, the rate of licking was higher in the changed component when that component was extinction (central shaded bars) than when it was a VI 10-s schedule (outer shaded bars). For the exception (Rat 105), the rate of drinking was higher in the changed component



THREE-SESSION MEANS

Fig. 1. Percentage deviation from baseline expressed as three-session means during 15 sessions of exposure to the contrast procedure, with water bottle present and water bottle absent for each subject in Experiment 1.

during extinction than during the second, but not the first, presentation of the VI 10-s.

Figure 2 also shows that the increased licking in the changed component during extinction is not well described as reallocation of licking from the other, constant component (unshaded bars). That is, the increase in licking was not consistently accompanied by a comparable decrease in licking in the constant component. A Pearson correlation coefficient confirmed this conclusion. There was almost no correlation between changes in the rate of

licking in the constant component and changes in the rate of licking in the changed component ($r = 0.09$).

DISCUSSION

The results of Experiment 1 replicate the findings of Dougan et al. (1985) by demonstrating positive contrast in rats' behavior when the schedules provided a high rate of reinforcement. In addition, the magnitude of contrast was smaller when an alternative response (water drinking) was available than

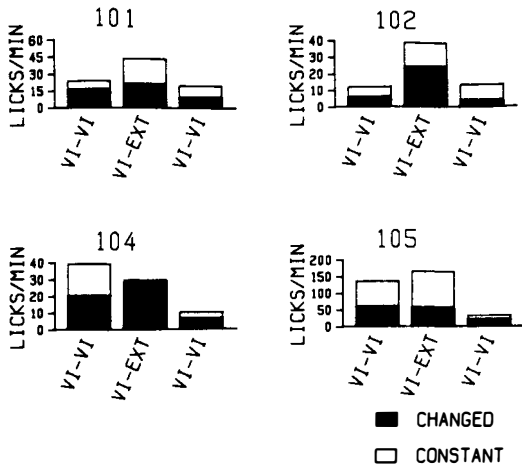


Fig. 2. Rate of licking in the changed (shaded bar) and constant (unshaded bar) component during each schedule in the conditions for which a water bottle was accessible during Experiment 1. The height of each bar represents the sum of licking rates in the two components. Note the use of different scales for different animals.

when it was not—a result consistent with predictions based on matching theory (Herrnstein, 1970). The effect of water-bottle availability was not similar to the findings of Hinson and Staddon (1978), who provided access to the alternative response of wheel running. Thus, the present results do not support competition theory (Ettinger & Staddon, 1982; Hinson & Staddon, 1978; Staddon, 1982).

The results of Experiment 1 also replicate the results obtained by Dougan *et al.* (1985) by showing that increases in the rate of drinking in the changed component are not well described as reallocation of drinking from the constant component. These results, again, are different from the findings of Hinson and Staddon (1978). They found that increases in wheel running during the extinction component were accompanied by roughly compensatory decreases in wheel running during the constant component (i.e., reallocation).

Drinking is likely to differ in many respects from running as an alternative response. One possible reason for the failure to obtain results similar to those of Hinson and Staddon is that the probability of the competing response differed between the studies. Hinson (personal communication, August, 1983) reported that the rats in the Hinson and Staddon study spent large portions (up to 50%) of the session run-

ning in the wheel. The rats in the present experiment spent far less time drinking. Experiment 2 was designed to assess whether increasing the probability of drinking would produce results more similar to those reported by Hinson and Staddon. It was designed as a systematic replication of Experiment 1 except that rats were deprived of water. It was assumed that water deprivation would, among other things, increase the probability of the alternative, drinking response.

EXPERIMENT 2

METHOD

Subjects

The subjects were 5 Sprague-Dawley rats obtained from the breeding colony at the Washington State University Psychology Department. All rats had extensive histories of food-reinforced responding on multiple schedules. Rats were housed individually and were maintained at approximately 80% of their free-feeding weights throughout the experiment.

Apparatus and Procedure

The apparatus was identical to that in Experiment 1. The procedure was identical to that in Experiment 1 except that the rats were water deprived. During the bottle-present condition, the rats received water only in the experimental apparatus. During the bottle-absent condition, the rats received access to water in their home cages immediately after their experimental sessions for a period of time equal to the time they had been in the experimental chamber.

RESULTS

The average rate of licking across all schedules in the present experiment was 79.5 licks per minute, compared to an average rate of 23.3 licks per minute in Experiment 1. A *t* test showed these differences to be significant, $t(7) = 4.44$; $p < .005$. This difference indicates that the water-deprivation manipulation was effective in increasing the rate of the alternative drinking response.

Rates of bar pressing in both components across each of the three schedules were calculated as in Experiment 1. These rates are presented in Table 3. Further examination shows that contrast occurred during both the

bottle-present and bottle-absent conditions for all animals.

The magnitude of behavioral contrast was calculated as in Experiment 1, and is presented as three-session means in Figure 3 for each subject in the experiment. The magnitude of contrast was greater for the bottle-present condition (overall mean of 36.4%) than for the bottle-absent condition (overall mean of 20.9%) for all subjects in the experiment, especially over the last nine sessions. The effect, however, was marginal for Subject 124. A two-tailed *t* test for repeated measures showed these differences to be significant, $t(4) = 3.51$; $p < .05$.

Figure 4 presents the rates of licking in both changed (shaded bar) and constant (unshaded bar) component across all three schedules in the bottle-present condition. The height of each bar represents the sum of the rates of licking in the two components of the multiple schedule. As seen in Figure 4, the rate of licking in the changed component during extinction (central shaded bars) was higher than it was during the corresponding VI 10-s schedules (outer shaded bars) for all animals.

Figure 4 suggests that the changes in the rate of licking in the changed component across schedules could be described as reallocation of licking from the constant component. For each animal the rate of licking was lower in the constant component (unshaded bars) of the multiple VI EXT than of the multiple VI VI schedules (both presentations). The absolute size of the change in licking in the changed component showed a strong correlation with the absolute size of the change in licking in the constant component across schedules ($r = .91$). Such a correlation would be predicted if reallocation did occur. Although there was some variation, the total amount of licking remained roughly constant across schedules. This result again suggests that changes in the rate of licking in one component could be described as reallocation from the other component.

DISCUSSION

Unlike the results of Experiment 1, in Experiment 2 the presence of a water bottle increased the magnitude of contrast relative to the level observed without a water bottle. This result is similar to those of Hinson and Staddon (1978) and appears to support the pre-

Table 3

Mean bar presses per minute during the constant (red light) component and during the changed (no light) component, for all animals on all schedules in Experiment 2.

Subject	Component	Schedule		
		VI 10-s VI 10-s	VI 10-s EXT	VI 10-s VI 10-s
Bottle present				
123	Constant	23.6	38.7	29.9
	Changed	24.7	25.0	25.6
124	Constant	32.8	42.9	37.5
	Changed	34.7	25.4	30.4
125	Constant	28.2	39.7	29.9
	Changed	28.6	22.3	20.8
126	Constant	35.4	47.6	36.9
	Changed	33.7	24.4	35.6
127	Constant	26.6	48.3	39.0
	Changed	25.4	21.5	31.1
Bottle absent				
123	Constant	24.4	37.2	29.7
	Changed	24.4	20.9	29.9
124	Constant	43.2	50.9	42.3
	Changed	41.4	26.3	36.9
125	Constant	30.6	35.8	31.0
	Changed	30.1	15.0	25.8
126	Constant	54.2	63.2	60.0
	Changed	58.7	43.4	59.8
127	Constant	44.2	54.2	45.0
	Changed	44.0	21.0	38.0

diction of competition theory over the prediction of matching theory.

Changes in the rate of drinking across schedules were also different from those in Experiment 1. There was a strong inverse relationship between changes in the licking rate across schedules in the changed and unchanged components. The sum of licking rates was also roughly constant across schedules. Thus, the change in the rate of licking from one component to the other when schedules changed could be described as reallocation. The finding of reallocation of water drinking in the present experiment appears similar to the reallocation of wheel running reported by Hinson and Staddon (1978), and lends support to the competition theory of behavioral contrast.

It might be that the effect of an alternative response on the magnitude of behavioral contrast depends on the probability of that alternative response. The procedure of the present experiment, however, differed from that used

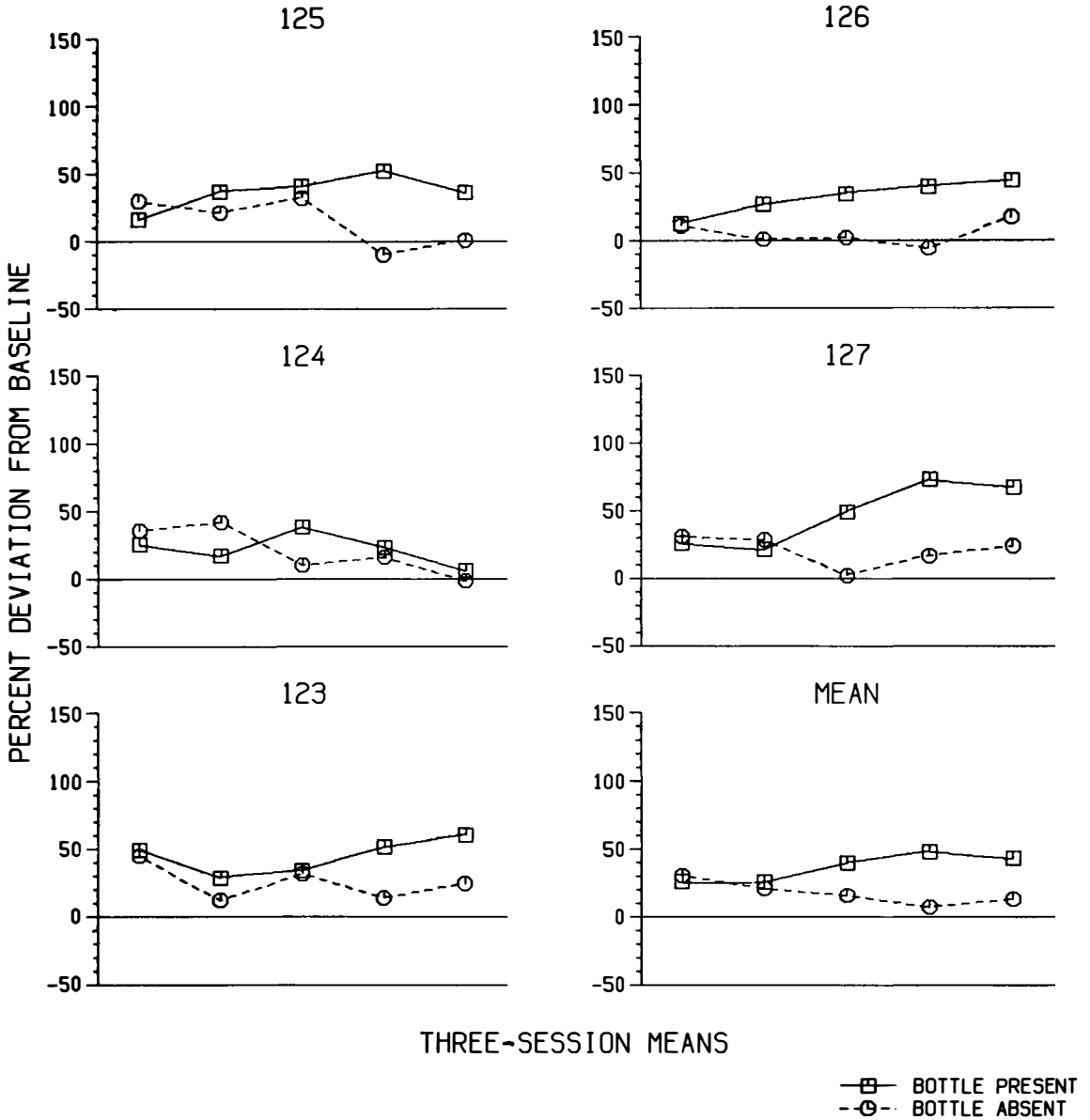


Fig. 3. Percentage deviation from baseline expressed as three-session means during 15 sessions of exposure to the contrast procedures, with water bottle present and with water bottle absent for each subject in Experiment 2.

by Hinson and Staddon (1978) in using a much higher rate of food reinforcement. Hinson and Staddon found contrast on multiple schedules that provided a relatively low rate of reinforcement (a baseline of multiple VI 60-s VI 60-s). The present experiment used a relatively high rate of reinforcement (multiple VI 10-s VI 10-s). Earlier experiments with rats in our laboratory (Dougan & McSweeney, 1985b; Dougan *et al.*, 1985)

failed to find reliable contrast on multiple VI 60-s VI 60-s schedules even with a water bottle present. It is possible that the earlier failure to find contrast on multiple VI 60-s VI 60-s was due to the low probability of alternative responding (i.e., the rats were not water deprived). Experiment 3 examined this possibility by using a procedure similar to that in Experiment 2. That is, food-deprived and water-deprived rats were tested for contrast

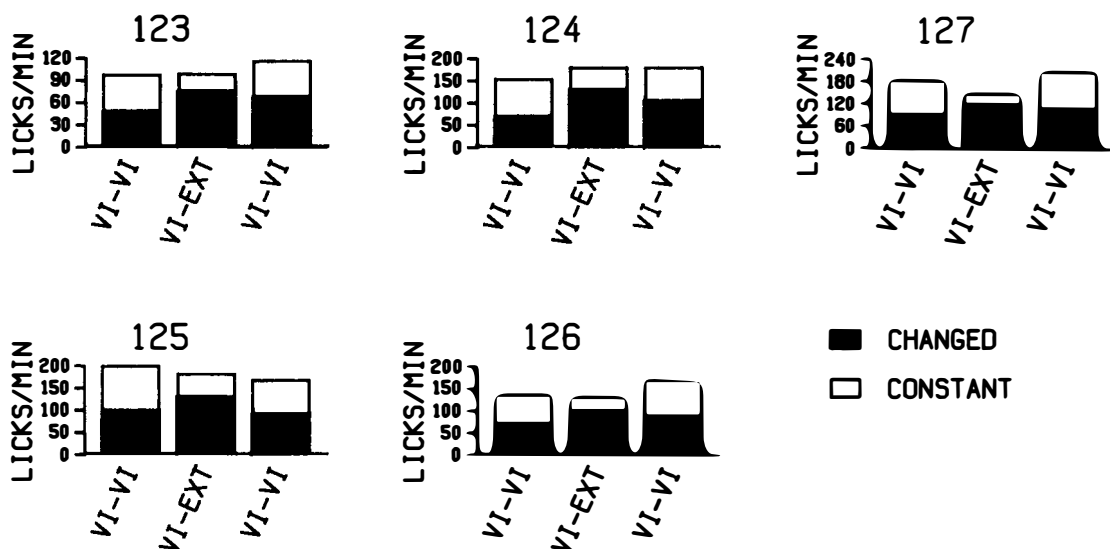


Fig. 4. Rate of licking in the changed (shaded bar) and constant (unshaded bar) components during each schedule in the conditions for which a water bottle was accessible during Experiment 2. The height of each bar represents the sum of licking rates in the two components. Note the use of different scales for different animals.

on multiple VI 60-s VI 60-s schedules of food delivery with an alternative water-drinking response available.

EXPERIMENT 3

METHOD

Subjects

The subjects were the same as those used in Experiment 2. They were maintained at approximately 80% of their free-feeding weights. Approximately 10 months elapsed between the completion of Experiment 2 and the start of Experiment 3, during which time they were exposed to a different multiple-schedule experiment. Subject 123 died during the interim, so Experiment 3 used only 4 rats.

Apparatus and Procedure

The apparatus was identical to that used in Experiments 1 and 2. The procedure was also identical with the following exceptions: Each rat was exposed to three multiple schedules, with each schedule in effect for 15 sessions. The first was a multiple VI 60-s VI 60-s schedule, the second was a multiple VI 60-s EXT schedule, and the third was identical to the first schedule. Sessions were conducted 6 to 7 days per week, and each session was ter-

minated when either 30 (multiple VI VI) or 15 (multiple VI EXT) reinforcers had been delivered. Subjects were water deprived as in Experiment 2—that is, they received water only while in the experimental apparatus. No water was available in the home cage.

RESULTS

Because of a mechanical failure, data from the last five sessions of the second multiple VI 60-s VI 60-s schedule (third schedule overall) have been excluded from the analysis. There-

Table 4

Mean bar presses per minute during the constant (red light) component and during the changed (no light) component, for all animals on all schedules in Experiment 3.

Subject	Component	Schedule		
		VI 60-s VI 60-s	VI 60-s EXT	VI 60-s VI 60-s
124	Constant	14.9	14.5	16.8
	Changed	15.1	11.1	17.5
125	Constant	14.7	12.1	17.9
	Changed	15.2	10.0	17.9
126	Constant	13.0	14.3	19.0
	Changed	13.0	11.3	19.6
127	Constant	14.7	14.9	14.2
	Changed	15.2	13.3	19.7

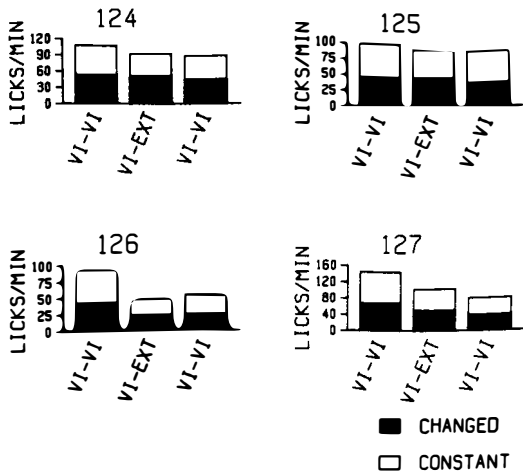


Fig. 5. Rate of licking in the changed (shaded bar) and constant (unshaded bar) components during each schedule in Experiment 3. The height of each bar represents the sum of licking rates in the two components. Note the use of different scales for different animals.

fore, data reported for that schedule are based on 10-day means instead of 15-day means.

Rates of bar pressing were calculated as in the previous experiments, and are presented in Table 4. Further examination reveals that none of the subjects exhibited positive behavioral contrast; however, response rates decreased in the changed component during extinction, indicating that the nonreinforcement of responding during extinction had some effect.

The rates of licking in both changed (shaded bars) and constant (unshaded bars) components are presented in Figure 5. There were no consistent changes in the rate of licking in either the changed or unchanged components across the three schedules.

DISCUSSION

The results of Experiment 3 extend the results reported by Dougan *et al.* (1985). Dougan and his colleagues failed to find either behavioral contrast or systematic changes in licking rate under the same series of schedules used in the present experiment. The experiments differed in that rats were water deprived in the present experiment but not in the Dougan *et al.* experiment.

The present results are not similar to those reported by Hinson and Staddon (1978), who reported contrast using a multiple VI 60-s VI 60-s schedule with wheel running as the al-

ternative response. Experiments 1 and 2 showed that water deprivation can produce results similar to those reported by Hinson and Staddon with schedules that provide a high rate of reinforcement and that provide water drinking as an alternative response. Experiment 3 showed that water deprivation does not produce these results when schedules provide a relatively low rate of reinforcement.

One procedural difference (in addition to the different alternative responses available) between the Hinson and Staddon experiment and the present experiment must be noted. Components alternated once every 60 s in the Hinson and Staddon experiment. Components alternated every 90 s in the present experiment. Although component duration does affect behavioral contrast in pigeons (see McSweeney, 1982), it seems unlikely that a difference of 60 s versus 90 s should be crucial. Dougan *et al.* (1985) failed to find differences in either behavioral contrast or interim behavior reallocation as a function of component duration when they used durations of 90 s and 30 s when rats served as subjects.

One caution must also be taken concerning the failure to find contrast in the present experiment. Although the rate of bar pressing in the changed component decreased during extinction for all animals, the decreases were relatively small. It is possible, therefore, that the failure to find contrast was due to poor discrimination between the components. However, behavioral contrast in rats is not always accompanied by good discrimination between components. For example, Dougan *et al.* (1985) found behavioral contrast in several rats that actually *increased* responding during extinction relative to baseline.

GENERAL DISCUSSION

The present data suggest that the opportunity to engage in an alternative response and the probability of that alternative response interact to determine the level of behavioral contrast. When the probability of water drinking was low (Experiment 1), the presence of a water bottle decreased the magnitude of positive behavioral contrast. When the probability of water drinking was high (Experiment 2), the presence of the water bottle increased the magnitude of positive behavioral contrast. When the probability of drinking was low,

interim behavior reallocation (Hinson & Staddon, 1978) did not occur. When the probability of drinking was high, interim behavior reallocation did occur.

Aspects of these results support both competition and matching theories, but under different conditions. The results support the prediction of matching theory when the probability of drinking was low (Experiment 1). The magnitude of contrast was lower when an alternative response was available. The results support the prediction of competition theory when water deprivation was high (Experiment 2). The magnitude of contrast was higher when an alternative response was available, and interim behavior reallocation occurred, as predicted by competition theory.

The present data suggest that a simple application of either matching or competition theory (as developed in the introductory section) will have trouble accounting for all instances of behavioral contrast. Although both competition and matching theories can account for some of the data, neither, without further elaboration, can account for the kinds of interaction that are observed. (Additive theories make no obvious predictions about alternative responding.)

Based on these results, it seems reasonable to argue that behavioral contrast is at least two distinct phenomena. In "noncompetitive" environments, in which there is only one high-probability response, contrast roughly follows the prediction of the matching law (but see McSweeney, 1980). In "competitive" environments, in which there is more than one high-probability response, contrast roughly follows the predictions of competition theory. Thus, competitive contrast and noncompetitive contrast may represent two different phenomena.

If there is a distinction between competitive and noncompetitive contrast, it is likely that noncompetitive contrast is the type that has received the greater amount of attention in the literature. Most contrast studies, especially those using pigeons, do not provide any high-probability alternative response, and thus do not arrange the conditions necessary for competitive contrast to occur.

It is important to note that the present analysis is based on the interpretation of water availability and water deprivation as affecting mainly the probability of a competing re-

sponse. Those operations, however, might have more complex effects that would make the relevance of the data for the theories of contrast difficult to evaluate. For example, when the rats were not water deprived, at least some of the drinking that occurred presumably was schedule-induced (Falk, 1961; Staddon, 1977). If so, changing one of the components of the multiple schedule to extinction could have changed the evocative conditions for drinking. In terms of Equation 2, R_z would be changing in unknown ways, which would make it difficult to be sure what effect the equation predicts in the conditions that the water bottle was available. Similarly, it may not be appropriate to think of r_0 in Equation 1 as remaining constant (see also Dougan & McSweeney, 1985a, for a similar discussion).

As another example, it is possible that water deprivation decreased the reinforcing potency of dry food (Pliskoff & Tolliver, 1960). If so, the reinforcing potency of dry food in the constant component might vary directly as a function of the amount of drinking that occurred in the changed component. In other words, r_1 of Equation 1 and R_x of Equation 2 might not be viewed as remaining effectively constant as the alternative component is changed. Such effects would complicate an evaluation of the two theories on the basis of the present data.

Even if some of the effects suggested above did occur, the present data still cause problems for the theories. If the "constants" in a model change independently of the operations of which they are assumed to be a function, then their utility as explanatory concepts is questionable (see also Dougan & McSweeney, 1985a; Timberlake, 1982). For the theories to be able to account for the present data in anything other than a post hoc fashion, it will be necessary to develop a clearer understanding of the interactions between the terms of the model that represent alternative reinforcement, as they are affected by the kinds of manipulations used here.

The present results, in conjunction with earlier studies, also suggest that the rate of reinforcement provided by the multiple schedule and the form of the alternative response interact to affect contrast. If so, the operations performed here should be interpreted as doing more than merely affecting the probability of an alternative response. Hinson and Staddon,

using a multiple VI 60-s VI 60-s schedule with wheel running as an alternative response, found both contrast and reallocation of interim behavior. In the present study, using water drinking as an alternative response, contrast and reallocation were not found on a multiple VI 60-s VI 60-s schedule (Experiment 3) but were found at higher rates of reinforcement (Experiment 2). Although the comparison of the present study with Hinson and Staddon suggests an interaction, the cross-study comparison is not a strong test. This question deserves further study in a single experiment that includes both conditions.

There are several reasons for suspecting that drinking and wheel running might differ in ways relevant to the kinds of studies conducted here. First, drinking and wheel running may differ in "competitiveness." According to competition theory, the more competitive an interim response, the better it will be able to produce behavioral contrast (Staddon, 1982). Second, water regulation is closely related to food regulation in animals. As Hursh (1984) has argued, food and water consumption are complementary in that there is an optimal ratio of food consumption to water consumption. No such relationship is known to exist between food consumption and wheel running. Third, water consumption and wheel running have different temporal properties when they serve as interim responses (Staddon & Ayres, 1975). Temporal properties may be important in determining how alternative responses influence behavioral contrast. Finally, water drinking and wheel running may differ because they serve different functions in the animal's natural behavior system. Timberlake (1983) has argued that the significance of a response in an animal's natural behavioral repertoire will influence the function of that response in laboratory studies. Following this analysis, water drinking is a consummatory response in the natural environment whereas running is a response seen in foraging and other activities. Thus, the ecological significance of wheel running and water drinking may influence the way in which they serve as interim activities.

Another aspect of the present results that deserves further attention is the time course of drinking over the session. Although no intrasession response distributions were recorded, informal observations suggested that

rats under water deprivation did much of their drinking at the beginning of the session. In contrast, drinking by rats that were not water deprived seemed to be distributed more evenly across the session. Thus, there appear to be within-session changes in the interaction between bar pressing and drinking that deserve further study.

In conclusion, the present data suggest that there may be two types of behavioral contrast, one based on matching, the other on competition. Future research needs to examine the conditions under which each of these types of contrast occurs, as well as the properties of potential alternative responses.

REFERENCES

- Catania, A. C., & Reynolds, G. S. (1968). A quantitative analysis of the responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, *11*, 327-383.
- Dougan, J. D., & McSweeney, F. K. (1985a). Variation in Herrnstein's r_0 as a function of alternative reinforcement rate. *Journal of the Experimental Analysis of Behavior*, *43*, 215-223.
- Dougan, J. D., & McSweeney, F. K. (1985b). *Are behavioral contrast and operant-Pavlovian summation equivalent?* Manuscript submitted for publication.
- Dougan, J. D., McSweeney, F. K., & Farmer, V. A. (1985). Some parameters of behavioral contrast and allocation of interim behavior in rats. *Journal of the Experimental Analysis of Behavior*, *44*, 325-335.
- Ettinger, R. H., & Staddon, J. E. R. (1982). Behavioral competition, component duration and multiple-schedule contrast. *Behaviour Analysis Letters*, *2*, 31-38.
- Falk, J. L. (1961). Production of polydipsia in normal rats by an intermittent food schedule. *Science*, *133*, 195-196.
- Gamzu, E., & Schwartz, B. (1973). The maintenance of key pecking by stimulus-contingent and response-independent food presentation. *Journal of the Experimental Analysis of Behavior*, *19*, 65-72.
- Hearst, E., & Jenkins, H. M. (1974). *Sign-tracking: The stimulus-reinforcer relation and directed action*. Austin, TX: Psychonomic Society.
- 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., (1978). Behavioral competition: A mechanism for schedule interactions. *Science*, *202*, 432-434.
- Hursh, S. R. (1984). Behavioral economics. *Journal of the Experimental Analysis of Behavior*, *42*, 435-452.
- McSweeney, F. K. (1980). Differences between rates of responding emitted during simple and multiple schedules. *Animal Learning & Behavior*, *8*, 392-400.
- McSweeney, F. K. (1982). Positive behavioral contrast when pigeons press treadles during multiple schedules. *Journal of the Experimental Analysis of Behavior*, *39*, 149-156.
- Pliskoff, S., & Tolliver, G. (1960). Water-deprivation-

- produced sign reversal of a conditioned reinforcer based upon dry food. *Journal of the Experimental Analysis of Behavior*, **3**, 323-329.
- Rachlin, H. (1973). Contrast and matching. *Psychological Review*, **80**, 217-234.
- Reynolds, G. S. (1961). Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, **4**, 57-71.
- Staddon, J. E. R. (1977). Schedule-induced behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 125-152). Englewood Cliffs, NJ: Prentice-Hall.
- Staddon, J. E. R. (1982). Behavioral competition, contrast and matching. In M. L. Commons, R. J. Herrnstein, & H. Rachlin (Eds.), *Quantitative analyses of behavior: Vol. 2. Matching and maximizing accounts* (pp. 243-261). Cambridge, MA: Ballinger.
- Staddon, J. E. R., & Ayres, S. L. (1975). Sequential and temporal properties of behavior induced by a schedule of periodic food delivery. *Behaviour*, **54**, 26-49.
- Timberlake, W. (1982). The emperor's clothes: Assumptions of the matching theory. In M. L. Commons, R. J. Herrnstein, & H. Rachlin (Eds.), *Quantitative analyses of behavior: Vol. 2. Matching and maximizing accounts* (pp. 549-568). Cambridge, MA: Ballinger.
- Timberlake, W. (1983). The functional organization of appetitive behavior: Behavior systems and learning. In M. D. Zeiler, & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol. 3. Biological factors in learning* (pp. 177-221). Chichester, England: Wiley.
- Williams, B. A. (1983). Another look at contrast in multiple schedules. *Journal of the Experimental Analysis of Behavior*, **39**, 345-384.
- Williams, B. A., & Wixted, J. T. (1986). An equation for behavioral contrast. *Journal of the Experimental Analysis of Behavior*, **45**, 47-62.

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