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## SOME PARAMETERS OF BEHAVIORAL CONTRAST AND ALLOCATION OF INTERIM BEHAVIOR IN RATS

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Two experiments examined the effects of baseline reinforcement rate and component duration on behavioral contrast and on re-allocation of interim behavior in rats. Positive behavioral contrast occurred during multiple variable-interval 10-second extinction (VI 10 EXT) after a multiple VI 10 VI 10 baseline condition, but not during multiple VI 60 EXT following multiple VI 60 VI 60 baseline. Component duration had no significant effect on contrast. These results differed from those found in studies of pigeons' key pecking. Contrast was accompanied by an increased rate of drinking in the changed component, but drinking in the constant component did not decrease. These results are not consistent with the competition theory of contrast, but are consistent with the predictions based on the matching law. However, no current theory seems to account for all instances of behavioral contrast.

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

Reynolds (1961) found that when reinforcement rate was reduced in one component of a multiple schedule, response rate in the other, constant component increased. This effect is known as positive behavioral contrast. Hinson and Staddon (1978) demonstrated that the magnitude of behavioral contrast increases when there is an alternative to operant responding. Rats' food-reinforced responding on a multiple schedule showed more contrast when a wheel-running response was available than when it was not. These data are the major support for the competition theory of behavioral contrast (Ettinger & Staddon, 1982; Hinson & Staddon, 1978; Staddon, 1982). According to competition theory, contrast results from reduced competition between operant responding and alternative (interim) responding in the constant component. When the rate of reinforcement in the changed component is reduced, interim responses are re-allocated to that component, making them less competitive with instrumental responding in the other, constant component.

Several lines of evidence, however, have

suggested that the relation between contrast and re-allocation of interim behavior is more complex than competition theory suggests. For example, Williams (1983) argued that subjects with a running response available in the Hinson and Staddon (1978) experiment showed better discrimination than the subjects without the running wheel. The greater degree of contrast shown by these subjects may have occurred because of better discrimination rather than because of competition. Dougan and Eacker (1982) found that a competing response can interfere with changes in operant responding. With a licking response available, bar pressing changed less than it changed when a licking response was unavailable. Jacquet (1972) found re-allocation of interim licking responses to a multiple schedule component by providing a higher rate of reinforcement, a result opposite to that reported by Hinson and Staddon.

Several variables may be responsible for these differences between Hinson and Staddon's (1978) report and other reports of behavioral contrast. First, the alternative response utilized by Dougan and Eacker (1982) and Jacquet (1972) was licking, whereas Hinson and Staddon used wheel running. Licking and wheel running may be affected differently by schedule parameters when they serve as alternative responses (Staddon, 1977; Staddon & Ayres, 1975).

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Second, Dougan and Eacker (1982) used a high reinforcement rate during baseline conditions (fixed-interval 5-s), whereas Hinson and Staddon used a lower rate (variable-interval 60-s). Reinforcement rate during baseline schedules appears to be an important variable in the production of contrast, although its effects are complex. When a key peck is the operant for pigeons, the magnitude of contrast varies inversely with baseline reinforcement rate (Reynolds, 1963; Spealman & Gollub, 1974). When a treadle press is the operant, magnitude of contrast is directly proportional to baseline reinforcement rate (McSweeney, 1978, 1983).

Third, Jacquet (1972) utilized a long (10-min) component duration. The magnitude of behavioral contrast generally varies inversely with component duration (Ettinger & Staddon, 1982; Hinson, Malone, McNally, & Rowe, 1978; McSweeney, 1982; Schwartz, 1978; Shimp & Wheatley, 1971; Spealman, 1976; Todorov, 1972; Williams, 1979, 1980). Component duration also should affect re-allocation of interim responses (Ettinger & Staddon, 1982; Staddon, 1982).

Finally, Hinson and Staddon (1978) used rats as subjects. Although contrast has been demonstrated in rats (Beninger & Kendall, 1975; Blough, 1980; Bradshaw, Szabadi, & Bevan, 1978; Gutman, 1977; Gutman, Suterer, & Brush, 1975; Nallan & McCoy, 1979; Uhl & Homer, 1974; Wilkie, 1972), the effect is not consistent (Schwartz & Gamzu, 1977). Contrast in pigeons, on the other hand, is very reliable (Williams, 1983). If contrast in rats is different than contrast in pigeons, then the generality of Hinson and Staddon's results is questionable.

The present experiments tested the generality of Hinson and Staddon's results by examining three questions. First, the magnitudes of contrast and re-allocation were examined as functions of both baseline reinforcement rate and component duration. Although the effects of these parameters on behavioral contrast in pigeons are well known, their effects on interim behavior re-allocation are not known. Second, contrast and interim behavior re-allocation were examined using a different interim response (licking) than that used by Hinson and Staddon. Third, the present experiments used rats as subjects to allow comparison with studies using pigeons. Al-

though the literature on contrast contains many parametric examinations of behavioral contrast in pigeons, there are few such studies using rats (Williams, 1983).

## EXPERIMENT 1

### METHOD

#### *Subjects*

The subjects were five 90-day-old Sprague-Dawley rats (101, 102, 103, 104, and 105) from the breeding colony at Washington State University. Each was housed in a separate cage and was maintained at approximately 80% of its ad-lib weight.

#### *Apparatus*

The apparatus was a standard operant conditioning unit for rats, 24 by 30 by 19 cm. Three 5-W lights were spaced evenly in the front wall, 15 cm from the wire grid floor. The two side lights were 10 cm from the center light and 1 cm from the closest wall. During the experiment, the left (red) light served as a discriminative stimulus; the center (white) light was illuminated constantly during the session.

A food cup was in the lower left corner of the front wall, 4 cm from the floor and 4 cm from the left wall. A response bar was located directly above the food cup, 10 cm from the floor and 6 cm from the left wall. The bar was connected to a microswitch that required a force of approximately 0.3 N to operate.

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. Contact with the tip of the drinking tube activated a lickometer circuit. The apparatus was housed in a sound-attenuating chamber, with an exhaust fan masking sounds from the electromechanical programming equipment.

#### *Procedure*

The bar-press response was shaped by successive approximations, with single 45-mg Noyes pellets as reinforcers. Subjects then were exposed to a series of multiple variable-interval variable-interval (multiple VI VI) schedules. The top half of Table 1 shows the order of conditions, the number of reinforcers available per session, and the number of sessions that each schedule was in effect. Experiment

1 consisted of two conditions. In the first (hereafter referred to as the low baseline condition), the baseline schedule was multiple VI 60-s VI 60-s. During the second (hereafter referred to as the high baseline condition), the baseline schedule was multiple VI 10-s VI 10-s. Each condition included three phases: an initial multiple VI VI baseline phase, a multiple variable-interval extinction phase (multiple VI EXT), and a return to the initial multiple VI VI schedule (McSweeney & Norman, 1979).

Each session terminated after a fixed number of reinforcers were delivered; this number varied across phases to keep session time constant. A stability criterion required that each subject's response rate in each component over the final five sessions on a schedule be within the range of response rates for all previous sessions on that schedule. Schedules were not changed until the performances of all subjects were stable. Sessions occurred 5 to 6 days per week.

When multiple VI EXT was in effect, the VI schedule and extinction were signaled, respectively, by the presence and absence of the red light. Components alternated every 90 s. The distribution of reinforcement intervals was constructed using the arithmetic series suggested by Catania and Reynolds (1968). Reinforcers available but uncollected when components changed were canceled.

## RESULTS AND DISCUSSION

Table 2 shows the mean and standard deviation of bar-pressing rate in each component. The data are means based on the last 15 sessions for each animal. Data from the initial baseline phase and the baseline recovery phase were averaged. Thus, means for the combined baseline and recovery (VI VI) phases were calculated over a total of 30 sessions; means for the VI EXT phase were calculated over 15 sessions.

Positive behavioral contrast is indicated by a higher rate of responding in the constant component during the VI EXT phase than during the combined multiple VI VI baseline phases. Only Rat 105 showed contrast in the low baseline condition. However, this rat's higher response rate during multiple VI EXT was due to a systematically decreasing response rate across all three phases and therefore cannot be considered behavioral contrast

Table 1

Order of schedules, reinforcers per session, and number of sessions conducted on each schedule.

Red light (constant component)	No light (changed component)	Reinforcers per session	Sessions to stability
Experiment 1: 90-s component duration			
Low baseline condition			
VI 60 s	VI 60 s	30	31
VI 60 s	EXT	15	20
VI 60 s	VI 60 s	30	35
High baseline condition			
VI 10 s	VI 10 s	120	39
VI 10 s	EXT	60	55
VI 10 s	VI 10 s	120	21
Experiment 2: 30-s component duration			
Low baseline condition			
VI 60 s	VI 60 s	30	47
VI 60 s	EXT	15	53
VI 60 s	VI 60 s	30	19
High baseline condition			
VI 10 s	VI 10 s	120	16
VI 10 s	EXT	60	16
VI 10 s	VI 10 s	120	15

(cf. McSweeney & Norman, 1979). During the high baseline condition, however, all animals showed contrast.

Table 3 shows the means and standard deviations of licking rate in both components during all phases of the experiment. Data from the initial baseline phase and the baseline recovery phase have been averaged. Again, means for the combined VI VI phases were calculated over a total of 30 sessions and means for the VI EXT phase were calculated over 15 sessions. In the high baseline condition, rats licked more in the changed component during multiple VI EXT than during multiple VI VI. In the low baseline condition, the rats licked less in the changed component during multiple VI EXT than during multiple VI VI. The increased licking during the changed component in the high baseline condition, however, was not accompanied by an equivalent decrease in licking during the constant component. This is illustrated in Figure 1, which shows the mean rate of licking in the constant (filled bar) and changed (unfilled bar) components during multiple VI VI baseline (V) and multiple VI EXT (E) phases. The height of each bar is the sum of responding in

Table 2

Means and standard deviations of bar-pressing rate (per minute) in both changed and constant components during VI VI baseline and VI EXT phases for each animal in Experiment 1.

Subject	Changed				Constant			
	VI VI		VI EXT		VI VI		VI EXT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low baseline condition								
101	12.70	5.66	2.95	1.90	12.30	5.70	9.20	2.78
102	11.29	7.00	2.73	1.00	10.30	6.90	6.30	1.60
103	6.43	2.95	2.95	0.97	6.90	2.10	6.10	1.10
104	13.75	4.70	6.66	2.70	13.90	4.50	12.00	3.45
105	9.65	5.60	9.06	4.41	9.00	5.40	11.00	2.82
High baseline condition								
101	44.98	17.40	7.23	3.80	44.60	16.10	75.20	17.80
102	37.19	9.70	4.36	3.80	38.20	9.00	48.80	9.50
103	43.34	13.05	6.77	6.05	44.20	11.56	55.10	14.20
104	27.11	7.80	9.17	5.90	27.80	8.90	46.00	8.90
105	34.32	14.08	5.66	2.10	36.40	13.40	39.40	8.00

both components. If the increased rate of licking in the changed component during multiple VI EXT phases resulted from an equivalent decrease in licking in the constant component, then the sum of the rates of licking in the constant and changed components should not change between multiple VI VI baseline and multiple VI EXT. This was not the case. Only Rat 104 showed a decrease in licking during the constant component that approached the increase in licking during the changed component, and this decrease was too small to ac-

count for the increase in the changed component.

The data in Figure 1 suggest a distinction between two types of interim behavior re-allocation. All rats in the high baseline condition increased licking in the changed component during multiple VI EXT. This constitutes re-allocation of interim behavior because the rat allocated a greater proportion of its total licking to the changed component. However, this proportional change in licking is not the same as the re-allocation reported by Hinson

Table 3

Means and standard deviations of licking rate (per minute) in both changed and constant components during VI VI baseline and VI EXT phases for each animal in Experiment 1.

Subject	Changed				Constant			
	VI VI		VI EXT		VI VI		VI EXT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low baseline condition								
101	16.60	8.50	6.30	5.30	21.24	17.50	8.97	3.90
102	22.60	16.30	11.10	10.00	24.22	16.70	18.75	7.60
103	15.90	12.40	13.50	5.90	10.94	6.38	10.92	4.60
104	7.00	3.30	6.80	2.50	9.35	6.20	5.46	2.95
105	143.00	24.30	39.80	24.30	149.81	43.30	146.56	36.00
High baseline condition								
101	13.20	17.03	34.20	17.12	8.51	8.90	13.57	12.40
102	5.50	8.96	74.80	28.70	7.54	10.70	3.82	6.90
103	3.20	6.14	59.40	31.40	0.08	0.39	3.21	12.02
104	14.00	13.25	29.30	9.56	10.96	17.08	0.46	1.73
105	43.60	33.90	97.70	39.90	41.63	38.03	17.38	19.70

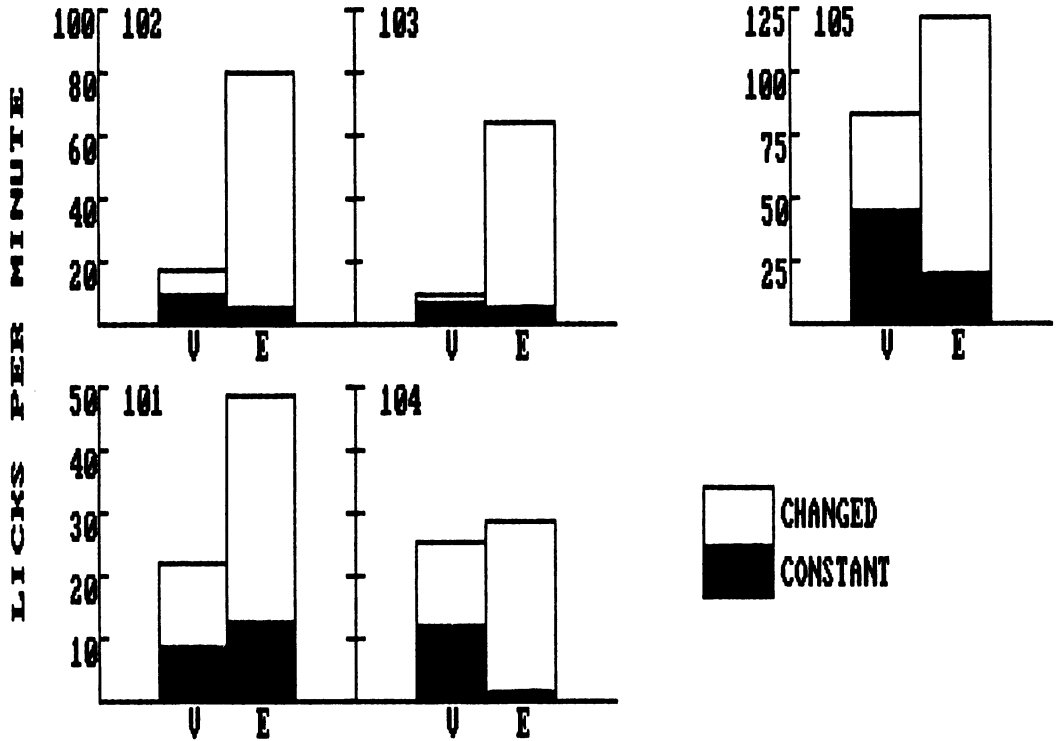


Fig. 1. Rate of licking in the constant (filled bar) and changed (unfilled bar) components during multiple VI VI baseline (V) and multiple VI EXT (E) phases in the high baseline condition of Experiment 1. The height of each bar represents the sum of licking rates in the two components. Note that different scales are used for different animals.

and Staddon (1978). They found an increase in interim behavior in the changed component and a decrease in interim behavior in the constant component.

The magnitude of behavioral contrast was determined by calculating the percentage difference in responding in the constant component between multiple VI VI and multiple VI EXT phases. A value of zero represents no change from baseline. A positive value indicates positive contrast, and a negative score indicates a decrease in responding in the constant component, or negative induction. The percentage deviations from baseline over the last 15 sessions of the VI EXT phase are plotted for each subject as three-session means in Figure 2. For 4 of 5 rats, the magnitude of contrast in the high baseline condition (filled circles) was greater than in the low baseline condition (unfilled circles). Negative induction was evident in the responding of 3 animals in the low baseline condition.

In Experiment 1, therefore, contrast occurred reliably only when the reinforcement

rate during baseline schedules had been high (multiple VI 10 VI 10). Contrast did not occur reliably when the baseline reinforcement rate was low (multiple VI 60 VI 60). Re-allocation of interim behavior also occurred only when the baseline reinforcement rate was high. However, the re-allocation was a proportional change in the distribution of licking between components, without evidence for re-allocation of licking directly from the constant component to the changed component, as reported by Hinson and Staddon (1978).

## EXPERIMENT 2

Experiment 2 replicated Experiment 1 using a shorter component duration.

## METHOD

### Subjects

The subjects were four 90-day-old Sprague-Dawley rats (113, 114, 115, and 116) from the colony at Washington State University.

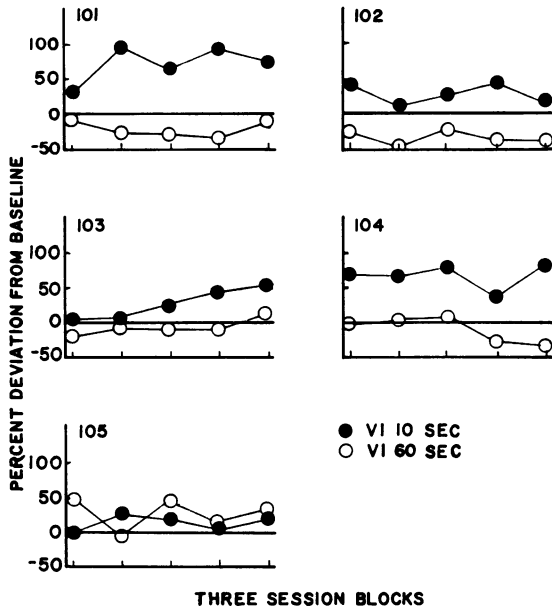


Fig. 2. Magnitude of contrast during Experiment 1 in the high baseline (filled circles) and low baseline (unfilled circles) conditions plotted as successive three-session means, for the last 15 sessions of the multiple VI EXT schedules. Component duration was 90 s.

Each was housed in a separate cage and was maintained at 80% of its ad-lib weight.

#### *Apparatus and Procedure*

The apparatus was identical to that used in Experiment 1. The procedure differed only in that components alternated every 30 s rather than every 90 s. The order of schedule presentations, the number of reinforcers per session, and the number of sessions per schedule are shown in the lower half of Table 1.

#### RESULTS AND DISCUSSION

Means and standard deviations of bar-pressing rate, computed over the last 15 sessions of each condition, are presented in Table 4. As in Table 2, data from the initial baseline phase and baseline recovery phase were averaged as described in Experiment 1. Only Rat 113 showed behavioral contrast in the low baseline condition, but all subjects showed contrast in the high baseline condition.

Table 5 shows the means and standard deviations of licking rate in both components during all phases of the experiment. Data from the initial baseline phase and the baseline re-

covery phase were averaged as in Experiment 1. Rats in the high baseline condition licked more often during the changed component of multiple VI EXT than they did in the same component during multiple VI VI baseline. This was not the case for the low baseline condition. Rat 115, and perhaps Rat 114, licked more during the changed component of multiple VI EXT than in the same component during multiple VI VI baseline. Rats 113 and 116 showed the opposite effect, with more licking during the changed component during multiple VI VI baseline than during multiple VI EXT.

The increased licking in the changed component during multiple VI EXT during the high baseline condition cannot be attributed to re-allocation from the constant component. Figure 3 shows the sum of licking in the constant (filled bar) and changed (unfilled bar) components during VI VI baseline (V) and VI EXT (E) phases. In no case was the increased licking in the changed component during VI EXT mirrored by a comparable decrease in the constant component.

Percentage deviations from baseline were calculated as in Experiment 1, and are presented in Figure 4 as three-session means over the last 15 sessions of multiple VI EXT. Negative induction occurred in 3 of 4 animals in the low baseline condition (unfilled circles); positive behavioral contrast occurred in all animals in the high baseline condition (filled circles).

Experiment 2, using a shorter component duration, therefore replicated the results of Experiment 1. When the baseline reinforcement rate was high (VI 10), the rate of licking increased in the changed component during multiple VI EXT. However, the increased rate of drinking in the changed component was not accompanied by a decrease in licking in the constant component. Behavioral contrast occurred reliably only when the reinforcement rate during baseline was high.

A two-factor mixed-design analysis of variance showed that magnitude of contrast varied strongly as a function of baseline reinforcement rate ( $F[1, 15] = 26.47$ ;  $p < .001$ ). Although the averaged data suggest a component-duration effect for contrast, the effect was not statistically significant ( $F[1, 6] = 0.33$ ;  $p > .10$ ). There were no significant interactions.

Table 4

Means and standard deviations of bar-pressing rate (per minute) in both changed and constant components during VI VI baseline and VI EXT phases for each animal in Experiment 2.

Subject	Changed				Constant			
	VI VI		VI EXT		VI VI		VI EXT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low baseline condition								
113	23.84	7.67	18.44	12.06	33.50	16.12	63.10	24.51
114	6.64	2.23	3.28	1.04	7.70	2.52	5.20	1.96
115	21.14	12.66	8.46	2.65	27.60	11.26	24.70	9.02
116	44.48	26.62	14.77	10.19	55.90	24.57	39.40	13.36
High baseline condition								
113	28.51	7.95	31.76	12.33	30.50	7.92	53.10	9.33
114	26.60	7.89	32.08	6.19	26.70	6.23	34.00	7.44
115	21.37	7.45	12.56	8.56	26.80	6.33	40.80	8.79
116	41.95	15.58	28.98	8.33	43.30	13.67	55.30	14.19

## GENERAL DISCUSSION

The present data support three major conclusions about behavioral contrast and re-allocation of interim behavior in rats. First, the data demonstrate changes in behavioral contrast in rats as affected by two variables: baseline reinforcement rate and component duration. The magnitude of contrast varied as a function of baseline reinforcement rate. Seven of 9 rats showed more contrast when the reinforcement rate during baseline schedules was high than when it was low. Component duration did not strongly affect the magnitude of contrast, although statistically nonsignificant trends were evident.

One note of caution should be made concerning the finding of contrast in the high baseline condition. A total of 120 reinforcers per session were presented during the multiple VI VI phases of the high baseline condition—a large number for a single session. If rats became satiated near the end of the VI VI baseline sessions, the rate of responding during these schedules may have decreased. However, the animals responded at a steady rate throughout the session. It is doubtful, therefore, that satiation contributed to the effects reported.

A second conclusion is that the re-allocation of interim wheel-running behavior reported

Table 5

Means and standard deviations of licking rate (per minute) in both changed and constant components during VI VI baseline and VI EXT phases for each animal in Experiment 2.

Subject	Changed				Constant			
	VI VI		VI EXT		VI VI		VI EXT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low baseline condition								
113	10.00	4.70	9.10	5.70	7.44	5.75	2.71	5.42
114	4.80	4.87	5.40	3.93	4.44	3.48	1.56	1.06
115	34.90	35.19	48.50	18.05	35.61	36.91	13.84	7.75
116	11.20	11.58	6.10	5.37	7.14	5.68	0.87	1.39
High baseline condition								
113	2.10	3.44	47.90	26.44	0.40	1.09	6.92	14.52
114	11.80	14.22	59.50	40.66	14.64	16.49	16.58	14.94
115	62.10	45.06	193.70	64.74	36.92	24.48	19.45	13.25
116	4.80	7.18	39.70	26.80	4.99	7.52	5.85	8.26



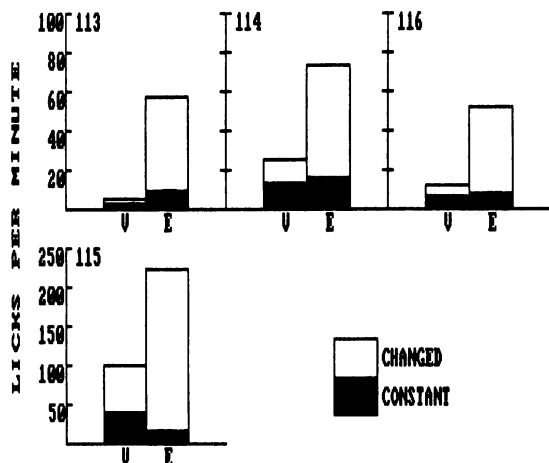


Fig. 3. Rate of licking in the constant (filled bar) and changed (unfilled bar) components during multiple VI VI baseline (V) and multiple VI EXT (E) phases in the high baseline condition of Experiment 2. The height of each bar represents the sum of licking rates in the two components. Note that different scales are used for different animals.

by Hinson and Staddon (1978) apparently does not occur in the case of a different interim response (licking). Under conditions comparable to those studied by Hinson and Staddon (multiple VI 60 VI 60 schedule during baseline), there was no evidence for re-allocation of licking, nor of behavioral contrast. Contrast was found with rates of reinforcement higher than those studied by Hinson and Staddon (multiple VI 10 VI 10), but there was no evidence of the kind of interim behavior re-allocation reported by Hinson and Staddon. They found an increased rate of wheel running in the changed component during the VI EXT phase accompanied by a decreased rate of running in the constant component. The present study found an increased rate of licking in the changed component during the VI EXT phase of the high baseline condition, but this increase was not accompanied by a decreased rate of licking in the constant component.

One possible reason for the differences between the re-allocation reported by Hinson and Staddon (1978) and the re-allocation reported here may be the properties of the interim response. Research has indicated that interim licking occurs immediately after reinforcement (Staddon & Ayres, 1975), although this is not always the case (Alferink,

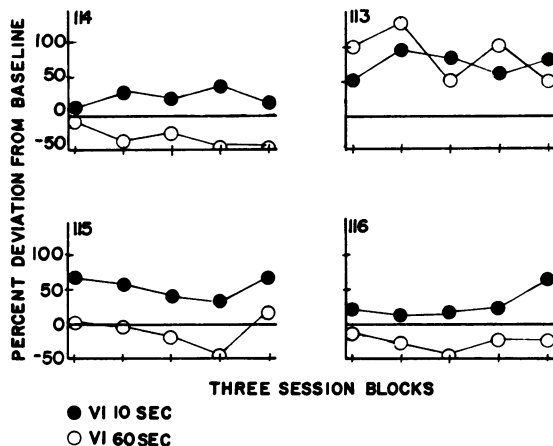


Fig. 4. Magnitude of contrast during Experiment 2 in the high baseline (filled circles) and low baseline (unfilled circles) conditions plotted as successive three-session means, for the last 15 sessions of the multiple VI EXT schedules. Component duration was 30 s.

Bartness, & Harder, 1980). Wheel running is not so limited to the immediate postfood interval (Staddon & Ayres, 1975). If interim licking is mainly a postreinforcement effect, it is not expected that it would be re-allocated to the extinction component.

Another reason for the differences between re-allocation reported by Hinson & Staddon (1978) and re-allocation in the present study may be the probability of the interim response. Hinson (personal communication, August 1983) reported that the rats in Hinson and Staddon's (1978) experiment spent up to half the total session in wheel running. Subjects in the present study spent a much smaller proportion of the session in licking. Recently, Dougan, McSweeney, and Farmer (1984) replicated the results reported by Hinson and Staddon (1978), using licking as the interim response. However, the replication occurred only when the rats were deprived of water, increasing the proportion of the session spent licking. Thus, the probability of the licking response may have been too low in the present study to observe the type of re-allocation reported by Hinson and Staddon.

A third conclusion to be drawn from the present study is that behavioral contrast for rats pressing bars may not change in the same way as contrast in pigeons pecking keys when the same variables are manipulated. First, a component-duration effect was not found. This

contradicts a well established effect in pigeons (Ettinger & Staddon, 1982; Hinson et al., 1978; McSweeney, 1982; Schwartz, 1978; Shimp & Wheatley, 1971; Spealman, 1976; Todorov, 1972; Williams, 1979, 1980). The two component durations used in the present experiment, however, may not vary over a sufficiently wide range to show an effect, so further research is indicated. Second, in two studies in which pigeons were used as subjects (Reynolds, 1963; Spealman & Gollub, 1974), the magnitude of contrast decreased as a function of baseline reinforcement rate, the opposite of the present effect with rats. Finally, behavioral contrast in the present study occurred reliably only when the reinforcement rate during baseline was high (multiple VI 10 VI 10). Contrast did not occur when the baseline schedule was multiple VI 60 VI 60, a value that commonly produces contrast in pigeons. This may explain why some authors (Rachlin, 1973; Schwartz & Gamzu, 1977) have concluded that contrast does not occur in rats. The high reinforcement rates that resulted in contrast in the present study have not been used in most studies of behavioral contrast.

The present data parallel those obtained when pigeons press treadles on multiple schedules. The finding of positive contrast for treadle pressing with high (McSweeney, 1983) but not low (McSweeney, 1978) baseline reinforcement rates was replicated in the present study. There are several possible reasons for these differences between contrast with key pecking and contrast with bar pressing or treadle pressing. These differences could result from differences in the sensitivity of responses to reinforcers (Staddon, 1982), from differences in the nature of signal-directed responding (Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977), or from the ecological "preparedness" of the animal to make the response (Seligman, 1970). In any case, it is impossible at this time to determine which, if any, of these alternatives is correct. The present data indicate that generality of the laws of contrast across species and response systems should not be assumed. Perhaps the most fruitful approach to future research would be to examine functional changes in contrast in a comparative fashion across species and response systems.

The present data cause problems for the

competition theory of behavioral contrast. The failure to find the re-allocation reported by Hinson and Staddon suggests that competition theory is not a general explanation of behavioral contrast. Competition theory requires a decrease in interim behavior during the constant component because the decreased rate of interim behavior is what allows bar pressing to increase in that component (Ettinger & Staddon, 1982; Hinson & Staddon, 1978; Staddon, 1982). Therefore, because licking did not decrease in the constant component, competition theory cannot explain the contrast observed in the high baseline condition.

It is possible that changes in the rate of licking in the present study did not reflect changes in the rate of other, unmeasured activities. Thus, a decrease in "other" behavior during the constant component might allow the rate of bar pressing to increase. However, explanations in terms of other, unmeasured activity are not useful because they render competition theory untestable (see also Dougan & McSweeney, 1985). In addition, the rats in the present study spent almost all session time either bar pressing or licking. Therefore, it is doubtful that "other" behavior could have occurred at a sufficiently high rate to account for contrast.

The present data are consistent with a theory of contrast based on the matching law (Herrnstein, 1970, 1974, 1979). According to Herrnstein's (1970) equation, the magnitude of behavioral contrast should increase with increases in the rate of reinforcement during baseline schedules, as was observed in the present study. Herrnstein (1970) also predicted that changes in component duration will change the magnitude of contrast. However, prediction of a component-duration effect is through the addition of a parameter ( $m$ ) that is not a critical component of matching theory (Timberlake, 1982). Hence, the absence of a component-duration effect in the present data is not particularly damaging to the matching theory of contrast.

Although matching theory describes the present data, it fails to provide a general model for contrast. First, matching theory predicts that increases in reinforcement from unscheduled sources will decrease the magnitude of contrast. However, addition of an alternative source of reinforcement can increase the magnitude of contrast (Dougan et al., 1984; Hin-

son & Staddon, 1978). Second, Reynolds (1963) and Spealman and Gollub (1974) found an inverse relationship between magnitude of contrast and baseline reinforcement rate in the case of pigeons' key pecking. These studies contradict matching theory. Finally, derivation of the matching law requires that a number of assumptions be made concerning the control of behavior (Timberlake, 1982). Recently, several authors have questioned the validity of these assumptions (Dougan & McSweeney, 1985; McSweeney, Melville, & Whipple, 1983; Timberlake, 1982). As Timberlake has argued, the matching law cannot be considered a general theory of behavior unless the assumptions of matching can be supported.

The present data, therefore, do not provide any clear conclusions with regard to theories of behavioral contrast. The failure to find a decrease in interim drinking in the constant component during the VI EXT phase is a problem for competition theory, but other studies have supported the theory. The present data support matching theory, but data from several other studies do not. Perhaps these failures are indicative of problems in current theoretical approaches to contrast. Numerous theories have been proposed to account for contrast, and all account for some, but not all, of the data. Additive theories (Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973) explain results when a signal-key procedure is used (Keller, 1974), but fail to account for data on behavioral competition (Hinson & Staddon, 1978), or for contrast in pigeons' treadle pressing (McSweeney, 1983), or rats' bar pressing (as in the present study). Theories based on induced Pavlovian excitation (Gutman, 1977; Gutman & Maier, 1978) account for most of the data very well, but suffer from a lack of testability (Williams, 1983). These theoretical failures may be a result of attempts to explain contrast in terms of a single causal factor. It is possible that contrast is controlled by several factors, including competition, matching, signal-directed responding, and general Pavlovian excitation. In support of this idea, Dougan *et al.* (1984) have shown that both competition theory and matching theory may be correct, depending on the situation. Future research should investigate situations in which

each of the above potential causal factors may be in operation.

In conclusion, contrast occurred reliably only when the reinforcement rate during baseline schedules was high. Contrast was not affected by component duration. Although interim drinking increased in the changed component in all cases where contrast occurred, this increase was not mirrored by a decrease in drinking in the constant component. These results are consistent with the matching theory of contrast rather than with competition theory. However, no current theory seems to provide a general explanation of behavioral contrast.

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