

*RATE OF CONDITIONED REINFORCEMENT AFFECTS OBSERVING RATE  
BUT NOT RESISTANCE TO CHANGE*

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The effects of rate of conditioned reinforcement on the resistance to change of operant behavior have not been examined. In addition, the effects of rate of conditioned reinforcement on the rate of observing have not been adequately examined. In two experiments, a multiple schedule of observing-response procedures was used to examine the effects of rate of conditioned reinforcement on observing rates and resistance to change. In a rich component, observing responses produced a higher frequency of stimuli correlated with alternating periods of random-interval schedule primary reinforcement or extinction. In a lean component, observing responses produced similar schedule-correlated stimuli but at a lower frequency. The rate of primary reinforcement in both components was the same. In Experiment 1, a 4:1 ratio of stimulus production was arranged by the rich and lean components. In Experiment 2, the ratio of stimulus production rates was increased to 6:1. In both experiments, observing rates were higher in the rich component than in the lean component. Disruptions in observing produced by pre-session feeding, extinction of observing responses, and response-independent food deliveries during intercomponent intervals usually were similar in the rich and lean components. When differences in resistance to change did occur, observing tended to be more resistant to change in the lean component. If resistance to change is accepted as a more appropriate measure of response strength than absolute response rates, then the present results provide no evidence that higher rates of stimuli generally considered to function as conditioned reinforcers engender greater response strength.

*Key words:* conditioned reinforcement, resistance to change, behavioral momentum, observing, reinforcement rate, key peck, pigeon

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Experiments examining the resistance to change of operant behavior have found that behavior maintained by relatively higher rates or larger magnitudes of reinforcement is relatively more resistant to disruption (see Nevin, 1992; Nevin & Grace, 2000, for reviews). In these experiments, responding typically is maintained on a multiple schedule of reinforcement in which the components arrange different reinforcement conditions. Following stability in responding, a disruptor is introduced (e.g., prefeeding, extinction) and resistance to change is measured as the decrease in responding relative to predisruption baseline rates (i.e., log proportion of baseline).

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Most experiments examining resistance to change have focused on responding maintained directly by primary reinforcement. Less is known about the resistance to change of responding maintained by conditioned reinforcement. In two-link chain schedules, completing a schedule requirement in the presence of an initial-link stimulus produces a transition to a terminal link in which completion of a schedule requirement produces food. Initial-link responding generally is considered to reflect the conditioned reinforcing effects of the terminal-link stimulus (e.g., Kelleher & Gollub, 1962). A common finding is that initial-link responding is less resistant to various disruptors than terminal-link responding (e.g., Ferster & Skinner, 1957; see Nevin, 1979, for review), suggesting that responding maintained by conditioned reinforcement is more easily disrupted than responding maintained by primary reinforcement.

Other experiments have examined how variations in parameters of primary reinforcement affect the resistance to change of responding maintained by conditioned reinforcers associated with those primary reinforcers (e.g., Nevin, Mandell, & Yarensky,

1981; Shahan, Magee, & Dobberstein, 2003). For example, Nevin et al. (1981) used a multiple schedule of chain schedules with pigeons to examine how parameters of primary reinforcement in the terminal links affected resistance to change of responding in the initial links. The components of the multiple schedule arranged two-link random-interval (RI) RI chain schedules on separate keys signaled by different colors. The initial links in both components were always RI 40-s schedules, and the relative rate and magnitude of the primary reinforcers in the terminal links were varied across conditions. Replicating the usual result with food-maintained behavior, responding was more resistant to change in the terminal link providing more frequent and larger primary reinforcers. As in the simple chain-schedule experiments described above, responding maintained by conditioned reinforcement (i.e., initial-link responding) was less resistant to disruption by alternative reinforcement and pre-session feeding than responding maintained by primary reinforcement (i.e., terminal-link responding). Most importantly, initial-link responding was more resistant to change in the component with relatively more frequent or larger primary reinforcers in the terminal link. Thus responding maintained by a conditioned reinforcer associated with more frequent or larger primary reinforcers was more resistant to change.

Similar results were obtained by Shahan et al. (2003) using a multiple schedule of observing-response procedures with pigeons. Each component of a multiple schedule arranged an observing-response procedure. In each component, unsignaled periods of exposure to an RI schedule of food delivery and extinction alternated unpredictably on a center key (i.e., mixed schedule). Pecks to a left key produced 15-s periods of access to stimuli differentially correlated with the RI (i.e., S+) and extinction periods (i.e., S-) on the center key. Different stimuli were used as S+, S-, and the mixed schedule stimulus in the two components. The RI schedule in the rich component arranged primary reinforcers at a rate 4 times higher than the RI in the lean component. The schedule of stimulus production on the observing key was always equal in the rich and lean components. Replicating the usual result, food-maintained responding in the rich component was more resistant to

change than food-maintained responding in the lean component. Consistent with previous chain schedule experiments, responding maintained by conditioned reinforcement (i.e., observing) also was less resistant to change than food-maintained responding during S+ presentations. Finally, observing was more resistant to change in the rich component where it produced stimuli associated with a higher rate of primary reinforcement than in the lean component where it produced stimuli associated with a lower rate of primary reinforcement. If observing responses are maintained by the conditioned reinforcing properties of S+ presentations (see Dinsmoor, 1983; Fantino, 1977, for reviews), these results are consistent with the findings of Nevin et al. (1981) in suggesting that responding maintained by a conditioned reinforcer associated with a higher rate of primary reinforcement is more resistant to change.

The experiments mentioned above suggest that the resistance to change of responding maintained by conditioned reinforcement is modulated by variations in parameters of the primary reinforcer. However, no experiments have examined the effects of variations in parameters of conditioned reinforcement (e.g., conditioned reinforcement rate) on resistance to change. As with primary reinforcement, increases in the rate of conditioned reinforcement produce increases in both absolute (e.g., Ferster & Skinner, 1957; Zimmerman, Hanford, & Brown, 1967) and relative (e.g., Baum, 1974; Davison, 1983; Williams & Dunn, 1991) response rates. To the extent that primary and conditioned reinforcement are functionally similar, responding maintained by higher rates of conditioned reinforcement should be more resistant to change than responding maintained by lower rates of conditioned reinforcement.

The present experiments used an observing-response procedure similar to that used by Shahan et al. (2003) to examine the effects of rate of conditioned reinforcement on resistance to change. The observing-response procedure was well suited for this purpose because, unlike chain schedules of reinforcement, it permitted variation in the rate of conditioned reinforcement while holding the rate of primary reinforcement constant. In a multiple schedule of observing-response

procedures, pigeons produced schedule-correlated stimuli at a high or low rate in two components. Unsignaled periods of an RI schedule alternated with extinction in both components. The rate of primary reinforcement provided by the RI schedule was the same in both components. In the rich component, observing responses produced schedule-correlated stimuli on an RI schedule at a higher rate. In the lean component, observing responses produced schedule-correlated stimuli on an RI schedule at a lower rate. Following stabilization of performance, resistance to change of observing was examined under conditions of disruption. In addition to providing an examination of the effects of rate of conditioned reinforcement on resistance to change, the present experiment provided an examination of the effects of rate of stimulus presentation on observing behavior. Few previous experiments have examined the effects of rate of stimulus presentation on observing, and each of those experiments varied ratio requirements for observing responses (e.g., Kelleher, 1958; Kelleher, Riddle, & Cook, 1962; Lieberman, 1972). Thus these previous experiments confounded changes in observing rates with changes in the rate of stimulus presentation. The present experiments avoided this problem by using RI schedules to arrange different rates of stimulus presentation.

## EXPERIMENT 1 METHOD

### *Subjects*

The subjects were 4 White Carneau pigeons maintained at approximately 80% of their free-feeding weights ( $\pm 15$  g) by postsession supplemental feeding as necessary. Pigeons 77, 210, 206, and 123 weighed 466 g, 430 g, 419 g, and 440 g, respectively. The pigeons varied in age and had extensive experience in other experiments. When not in the experimental sessions, the pigeons were housed in individual cages in a temperature-controlled colony with a 12:12 hr light/dark cycle (lights on at 7:00 a.m.) and had free access to water.

### *Apparatus*

The experiment was conducted in four Lehigh Valley Electronics pigeon chambers measuring 350 mm long, 350 mm high, and 300 mm wide. Three response keys were

centered on the front panel 83 mm apart (center to center) and were 240 mm above the floor. The keys measured 25 mm in diameter, and required about 0.1 N to operate. A projector could transilluminate each key with red, green, blue, yellow, a white plus sign with a black background, or a white triangle with a black background. Reinforcers consisted of 2-s presentations of pigeon checkers from a hopper. The hopper was accessible, when raised, through a 50 mm wide by 55 mm tall aperture located on the midline of the work panel with its center 100 mm from the floor. A 28-V DC clear bulb illuminated the aperture, and all other lights were extinguished when the hopper was operated. General illumination was provided by a shielded 28-V DC clear bulb mounted 45 mm above the center key. A ventilation fan and white noise masked extraneous sounds. Control of experimental events and data recording were conducted with Med Associates® programming and interfacing.

### *Procedure*

Pigeon 206 was initially trained on a two-component multiple schedule in which each component consisted of a two-component multiple schedule with an RI 60-s schedule and extinction alternating on the center key. The stimuli used in this initial training were the stimuli to be used in the multiple schedule of observing-response procedures (see below). Multiple-schedule training lasted 11 sessions and the baseline observing procedure was begun. Because Pigeons 77, 210, and 123 had participated in a previous experiment (see Shahan et al., 2003) using a similar procedure, they started immediately on the baseline multiple schedule of observing-response procedures. In the rich component, observing responses changed mixed-schedule stimuli to multiple-schedule stimuli at a high rate, whereas in the lean component, observing responses produced multiple-schedule stimuli at a lower rate.

All sessions began with a 30-s blackout followed by eight regularly alternating 5-min components that were separated by 30-s inter-component-intervals (ICIs) during which the houselight and keylights were extinguished. Throughout each component, an RI 120-s reinforcement schedule and extinction alternated after variable times averaging 60 s, with durations ranging from 10 s to 110 s in 10-s

Table 1

Experiment 1. Sessions in the baseline conditions (BL) preceding each disruptor, observing rates, and food-key response rates during S+, S-, and the mixed-schedule stimuli in rich and lean components. Mean (*SD*) response rates from the final five sessions of each baseline condition are shown. Response rates are shown for each session of the disruption conditions (PF = prefeeding; EXT = extinction of observing).

Subject	Condition	Session	Response rate (responses per minute)							
			Rich				Lean			
			Observing	S+	S-	Mixed	Observing	S+	S-	Mixed
77	PF BL	33	26.9 (5.3)	102.5 (13.3)	0.2 (0.3)	46.4 (6.0)	10.1 (3.3)	128.4 (6.6)	1.0 (0.8)	32.5 (9.9)
	PF 35 g	1	39.2	101.6	0.2	25.0	17.4	103.6	0.5	14.4
	PF 35 g	1	34.3	99.3	0.2	23.4	11.4	91.9	2.3	23.6
	PF 35 g	1	15.5	82.4	0.0	50.7	7.4	90.3	1.3	17.3
	PF 35 g	1	11.0	81.4	0.0	18.8	6.2	104.6	0.0	17.6
	PF 35 g	1	21.4	83.6	0.2	33.1	7.9	93.8	0.5	10.6
	EXT BL	8	28.4 (4.0)	103.8 (18.9)	0.2 (0.3)	53.4 (6.1)	14.9 (1.8)	115.1 (17.4)	1.0 (1.1)	42.1 (4.7)
	EXT	1	35.0	-	-	44.6	9.2	-	-	37.4
	EXT	1	11.9	-	-	58.6	5.3	-	-	46.8
	EXT	1	12.4	-	-	62.3	2.3	-	-	45.7
	EXT	1	12.4	-	-	57.0	2.4	-	-	52.1
	EXT	1	12.6	-	-	48.4	1.5	-	-	46.8
	210	PF BL	67	22.2 (4.5)	60.8 (7.4)	0.2 (0.1)	18.1 (6.2)	10.8 (2.5)	77.0 (7.3)	0.0 (0.0)
PF 35 g		1	18.9	50.8	0.0	3.8	5.3	53.9	0.0	29.9
PF 35 g		1	18.5	20.3	0.0	3.6	4.4	25.6	0.0	23.2
PF 35 g		1	5.9	9.0	0.0	0.1	5.9	7.0	0.0	13.1
PF 35 g		1	8.0	20.4	0.0	0.9	2.0	10.0	0.0	9.2
PF 35 g		1	4.8	32.0	0.0	0.6	3.0	16.4	0.0	27.6
EXT BL		7	24.4 (4.7)	78.8 (12.4)	0.1 (0.1)	14.6 (8.5)	9.8 (1.5)	64.8 (9.1)	0.5 (0.9)	61.2 (8.4)
EXT		1	11.0	-	-	23.5	9.4	-	-	47.3
EXT		1	6.3	-	-	20.9	3.8	-	-	36.6
EXT		1	3.2	-	-	35.2	1.8	-	-	36.3
EXT		1	4.7	-	-	37.5	2.1	-	-	42.7
EXT		1	7.9	-	-	28.1	5.5	-	-	18.3
206		PF BL	18	60.4 (4.7)	38.4 (3.0)	2.2 (1.3)	0.2 (0.2)	17.7 (5.3)	41.7 (1.9)	10.6 (9.0)
	PF 35 g	1	54.1	27.0	0.2	0.1	16.0	43.8	0.0	14.7
	PF 35 g	1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PF 35 g	1	22.2	33.9	0.6	0.2	6.2	42.8	0.8	11.6
	PF 35 g	1	30.9	27.2	0.7	0.1	7.0	42.2	1.0	15.8
	PF 35 g	1	50.6	29.5	0.3	0.0	16.9	34.2	0.5	14.5
	EXT BL	8	60.3 (5.5)	63.4 (11.5)	0.7 (0.7)	0.2 (0.1)	10.7 (3.8)	63.3 (10.4)	2.4 (3.4)	43.3 (4.4)
	EXT	1	32.7	-	-	0.5	4.2	-	-	45.3
	EXT	1	26.8	-	-	8.2	1.0	-	-	43.7
	EXT	1	12.2	-	-	17.9	1.6	-	-	45.3
	EXT	1	4.2	-	-	36.0	0.6	-	-	54.1
	EXT	1	0.9	-	-	26.8	0.2	-	-	37.4
	123	PF BL	31	83.7 (11.5)	122.5 (5.2)	0.5 (0.3)	0.9 (0.1)	80.6 (4.9)	170.9 (6.6)	41.8 (22.7)
PF 35 g		1	55.2	138.7	0.7	0.2	43.8	189.9	0.4	0.1
PF 35 g		1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.6

Table 1  
(Continued)

Subject	Condition	Session	Response rate (responses per minute)							
			Rich				Lean			
			Observing	S+	S-	Mixed	Observing	S+	S-	Mixed
	PF 35 g	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PF 35 g	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PF 35 g	1	6.2	169.5	0.0	0.1	2.5	208.1	2.0	0.1
	EXT BL	8	75.6 (19.5)	137.3 (9.1)	0.7 (0.6)	0.5 (0.3)	48.3 (12.1)	180.5 (9.4)	0.4 (0.4)	0.2 (0.1)
	EXT	1	56.5	-	-	0.0	22.0	-	-	0.0
	EXT	1	60.2	-	-	0.0	19.8	-	-	0.0
	EXT	1	22.5	-	-	0.0	25.8	-	-	0.0
	EXT	1	33.0	-	-	0.0	25.6	-	-	0.0
	EXT	1	20.5	-	-	0.0	31.5	-	-	0.0

increments. Nondifferential mixed-schedule stimuli were presented on the center (i.e., food) and left (i.e., observing) keys. The right key was always dark and inoperative. For Pigeons 77 and 210, the mixed-schedule stimuli were a white plus sign on a black background in the rich component and a white triangle on a black background in the lean component. For Pigeons 206 and 123, the mixed-schedule stimuli were reversed for the rich and lean components.

The mixed-schedule stimuli remained on the keys unless a response occurred to the observing key. A response to the observing key changed the mixed schedule to a multiple schedule by producing 15-s exposure (exclusive of hopper time) to the multiple schedule stimuli on the left and center keys. In the rich component, observing responses produced the change from mixed-schedule to multiple-schedule stimuli on an RI 15-s schedule. In the lean component, observing responses produced the change from mixed-schedule to multiple-schedule stimuli on an RI 60-s schedule. Responses to the observing key during the 15-s stimulus presentations had no programmed consequences. For Pigeons 77 and 210, a blue key signaled the RI 120-s schedule (S+) and a yellow key signaled extinction (S-) in the rich component. In the lean component, a red key was used for S+ and a green key for S-. For Pigeons 206 and 123, the multiple-schedule stimuli were reversed across the rich and lean components. Transitions between RI schedules and extinction during a 15-s stimulus presentation were accompanied by the

appropriate change in stimulus conditions. Schedule transitions could not occur during hopper presentations, and hopper presentations were excluded from all timing throughout the experiment. Transitions between RI and extinction had no effect on undelivered stimulus presentations arranged for pecks to the observing key. Undelivered stimulus presentations were cancelled with transitions between the rich and lean components. Reinforcers arranged by an RI schedule but not delivered were held until the RI was presented again within a particular rich or lean component, but were canceled with transitions between the rich and lean components. A changeover delay prevented responses on the food key from producing food deliveries within 3 s of a response to the observing key. All RI schedules used throughout the experiment were arranged by sampling a probability gate every 0.75 s with the appropriate probability. Across baseline conditions, mean obtained overall primary reinforcement rates were the same in the rich and lean components ( $M = 0.2$  reinforcers/min,  $SD = 0.1$ ), and were near the programmed values. Across baseline conditions, the rates of S+ presentation in the rich ( $M = 1.8$  presentations/min,  $SD = 0.3$ ) and lean ( $M = 0.4$  presentations/min,  $SD = 0.1$ ) components were near those arranged by the RI schedules of stimulus (both S+ and S-) delivery. The obtained ratio of S+ presentation rates in the rich and lean components was 4.3:1.

These conditions remained in effect until observing rates (observing responses during

mixed schedule/time in mixed schedule) and response rates on the food key appeared stable in the rich and lean components as judged visually across at least five sessions. Sessions occurred at approximately the same time each day and typically were conducted 7 days per week.

**Disruption.** Following stability, the disruptive effects of home-cage prefeeding 30 min prior to a session were examined (cf. Nevin et al., 1981). Pigeons were fed 35 g for five consecutive sessions. Following prefeeding, running weights were reestablished and baseline reinstated. Next, five sessions of observing-response extinction occurred in which observing responses were recorded but no longer produced 15-s stimulus presentations. The RI and extinction schedules continued to alternate and, therefore, responses to the food key during the mixed schedule continued to produce reinforcement in both components as previously described. Table 1 shows the number of sessions in baseline and disruption conditions.

#### RESULTS

The top panel of Figure 1 shows observing rates in the rich and lean components. With the exception of Pigeon 123 in the first exposure to the baseline, observing rates were higher in the rich component than in the lean component. Observing rates did not differ systematically across the two baseline conditions. As a result of observing responses, the mean (*SD*) proportions of time spent in the presence of the schedule-correlated stimuli across exposures to the baseline condition in the rich and lean components were: 0.46 (0.04) and 0.16 (0.3) for Pigeon 77, 0.45 (0.04) and 0.18 (0.03) for Pigeon 210, 0.49 (0.03) and 0.17 (0.04) for Pigeon 206, and 0.45 (0.04) and 0.20 (0.03) for Pigeon 123.

The bottom panel of Figure 1 shows response rates on the food key for the rich and lean components during the mixed schedule and during S+ presentations. Response rates were always higher during S+ presentations than during the mixed schedule. Response rates in the mixed schedule were below one response per minute in the rich component for Pigeon 206 and in both components for Pigeon 123. Across pigeons, response rates did not differ systematically for the rich and lean components during S+ presentations or

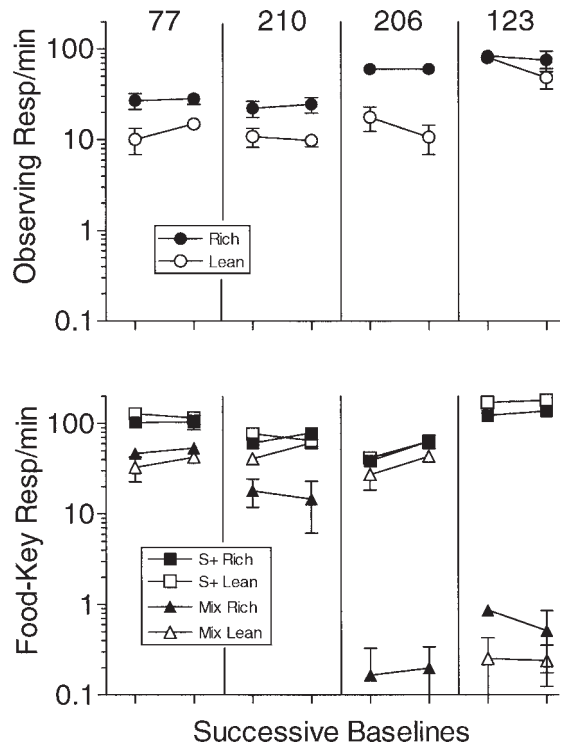


Fig. 1. Response rates in Experiment 1. The top panel shows mean observing rates in the rich and lean components across successive exposures to the baseline condition. The bottom panel shows mean food-key response rates during S+ and the mixed schedule. Means are calculated over the last five sessions of baseline prior to disruption. The y axis is logarithmic. Error bars represent  $\pm 1$  SD.

during the mixed schedule. Response rates during S- were low and not systematically different for the rich and lean components (see Table 1). Response rates did not differ systematically across the two exposures to the baseline.

Figure 2 shows an analysis of resistance to change in responding disrupted by pre-session feeding and extinction of observing responses. In each of the panels, the logarithm ( $\log$ ) of proportion of baseline response rates in the rich component is plotted as a function of  $\log$  proportion of baseline response rates in the lean component. Sessions in which response rates dropped to zero for one or both of the components are excluded from the figure. Absolute response rates are given in Table 1. The diagonal line represents where symbols would fall if the rich and lean components were equally disrupted. The overall magnitude of the disruption produced is indexed by the

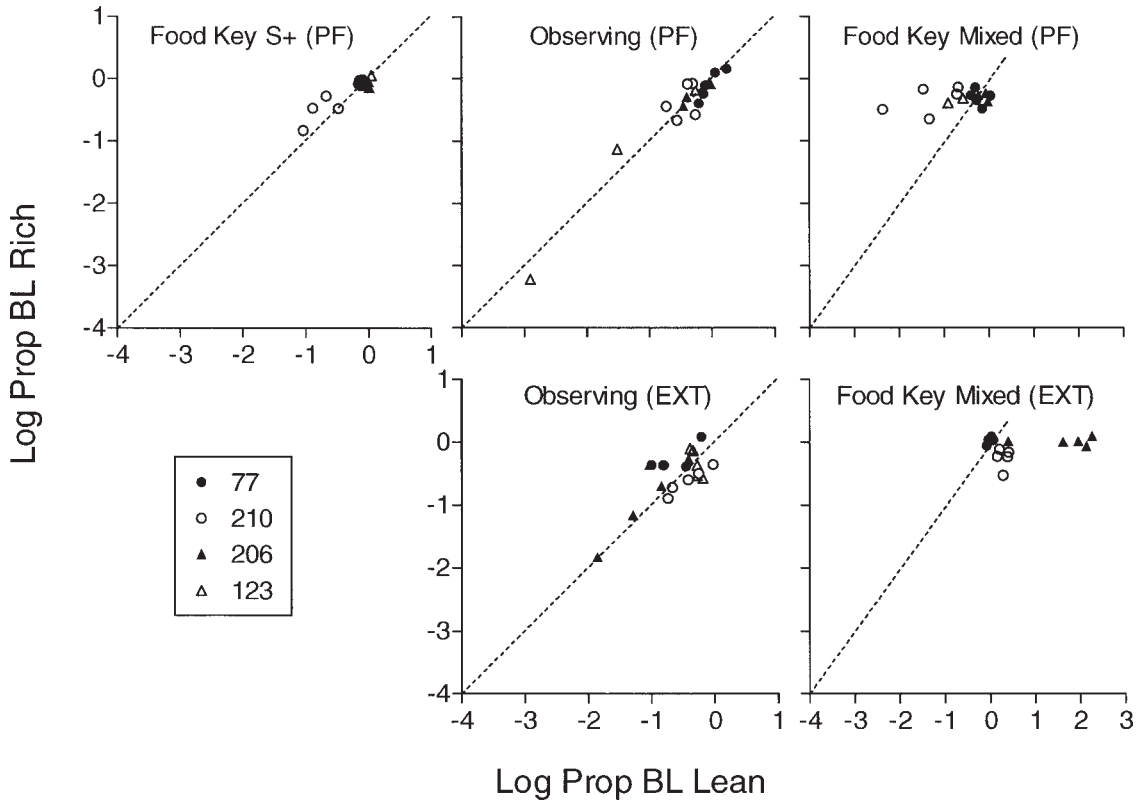


Fig. 2. Resistance-to-change analyses for Experiment 1. Log proportion of baseline in the rich component is plotted as a function of log proportion of baseline in the lean component during the disruption conditions of Experiment 1. Data from each session of each disruption condition are shown. PF and EXT refer to the prefeeding and extinction of observing.

degree to which the symbols extend down (i.e., rich component) and to the left (i.e., lean component). The top-left panel shows the analysis for food-key responding during S+ presentations for the five sessions of prefeeding. Responding on the food key during S+ was not differentially disrupted for the rich and lean components. A similar analysis is not presented for extinction of observing, because no S+ presentations could occur during extinction. The middle panels show analyses for observing responses in the five sessions of prefeeding and the five sessions of extinction of observing. Observing in the rich and lean components was not differentially disrupted by prefeeding or extinction of observing in the two components. For Pigeons 77, 206, and 123 prefeeding tended to disrupt observing more than food key S+ responding. However, with the exception of Pigeon 123, this effect was small. The right panels show analyses for

food-key responding during the mixed schedule. Prefeeding tended to disrupt mixed-schedule food-key responding more in the lean component than in the rich component, especially for Pigeon 210. During extinction of observing, however, mixed-schedule food-key responding often increased above baseline rate in the lean component (i.e., log proportion of baseline greater than 0).

DISCUSSION

Rates of observing were higher when observing responses produced more frequent schedule-correlated stimuli. Response rates and resistance to change of food-key responding in the rich and lean components did not differ systematically during S+ presentations. This result was expected because the rich and lean components arranged the same rates of food delivery. More surprising, however, was

Table 2

Experiment 2. Sessions in the baseline conditions (BL) preceding each disruptor, observing rates, and food-key response rates during S+, S-, and the mixed-schedule stimuli in rich and lean components. Mean (*SD*) response rates from the final five sessions of each baseline condition are shown. Response rates are shown for each session of the disruption conditions (PF = prefeeding; EXT = extinction of observing; FT = ICI FT-food).

Subject	Condition	Session	Response rate (responses per minute)								
			Rich				Lean				
			Observing	S+	S-	Mixed	Observing	S+	S-	Mixed	
77	PF BL	53	48.3 (4.3)	91.2 (15.2)	0.3 (0.2)	8.4 (3.1)	7.7 (0.9)	75.0 (12.3)	0.2 (0.3)	50.8 (6.7)	
	PF 20 g	1	51.5	89.4	0.2	1.9	11.5	95.5	0.0	36.1	
	PF 30 g	1	38.5	98.7	0.0	1.9	6.2	81.5	1.4	16.4	
	PF 40 g	1	32.0	99.9	0.0	1.6	4.8	77.2	0.0	13.3	
	PF 40 g	1	0.1	12.0	0.0	0.0	0.0	0.0	0.0	0.0	
	PF 40 g	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	EXT BL	25	77.5 (2.0)	110.9 (9.4)	0.8 (1.0)	3.9 (2.2)	12.8 (1.5)	119.3 (15.7)	0.4 (0.5)	64.1 (7.1)	
	EXT	1	84.1	-	-	2.1	10.6	-	-	44.2	
	EXT	1	42.2	-	-	36.2	3.5	-	-	90.2	
	EXT	1	13.5	-	-	76.4	2.8	-	-	92.3	
	EXT	1	4.3	-	-	34.6	0.4	-	-	51.6	
	EXT	1	10.6	-	-	61.0	2.3	-	-	99.0	
	FT BL	34	36.7 (5.1)	64.7 (3.5)	0.5 (0.5)	22.0 (2.9)	5.2 (1.2)	40.0 (5.4)	0.4 (0.7)	71.8 (4.9)	
	FT .75	1	26.2	49.0	0.9	38.1	4.1	33.6	0.0	30.8	
	FT .75	1	18.0	68.8	0.3	47.8	8.3	59.2	0.0	54.9	
	FT .75	1	18.2	61.9	1.4	54.5	8.0	61.6	0.0	56.3	
	FT .75	1	11.3	52.6	1.5	47.3	6.8	43.4	0.0	48.1	
	FT .75	1	15.3	56.2	0.2	41.5	12.4	52.4	0.0	58.8	
	210	PF BL	71	44.2 (4.2)	87.4 (10.1)	0.2 (0.3)	1.9 (1.5)	2.8 (0.5)	85.3 (9.4)	0.0 (0.0)	50.3 (3.4)
		PF 20 g	1	37.8	94.0	0.5	0.4	5.9	100.7	0.9	45.1
PF 30 g		1	31.5	89.8	0.4	0.6	5.4	75.9	0.0	45.4	
PF 40 g		1	1.1	46.0	0.0	0.0	1.0	88.4	2.7	7.2	
PF 40 g		1	0.1	0.0	0.0	0.4	0.7	55.8	0.0	2.9	
PF 40 g		1	0.2	42.9	0.0	3.7	0.2	127.7	39.4	5.3	
EXT BL		28	61.6 (2.6)	97.8 (4.4)	0.2 (0.1)	6.2 (1.9)	6.0 (0.8)	86.8 (9.8)	0.1 (0.3)	46.4 (8.0)	
EXT		1	30.4	-	-	34.2	4.6	-	-	40.2	
EXT		1	4.2	-	-	44.7	1.2	-	-	34.5	
EXT		1	1.3	-	-	34.7	1.2	-	-	35.7	
EXT		1	0.6	-	-	23.5	0.1	-	-	32.1	
EXT		1	1.2	-	-	31.8	0.4	-	-	39.7	
FT BL		41	25.1 (4.4)	58.8 (11.8)	0.1 (0.1)	9.8 (2.0)	2.5 (1.2)	71.0 (12.2)	0.0 (0.0)	24.5 (8.0)	
FT .75		1	7.8	23.8	0.0	10.9	1.1	42.0	0.0	13.1	
FT .75		1	2.6	18.4	0.4	8.7	0.5	27.4	0.0	5.0	
FT .75		1	1.8	0.3	0.0	9.8	0.1	0.0	0.0	1.9	
FT .75		1	0.4	3.9	0.0	2.9	0.0	0.0	0.0	1.4	
FT .75		1	0.8	24.8	0.0	12.0	0.2	61.6	0.0	4.7	
206		PF BL	31	49.0 (3.6)	50.0 (3.6)	0.1 (0.1)	3.0 (2.0)	8.7 (0.9)	55.3 (5.8)	0.1 (0.3)	45.7 (4.0)
		PF 20 g	1	53.1	54.3	0.3	2.9	8.4	60.3	0.0	41.4

Table 2  
(Continued)

Subject	Condition	Session	Response rate (responses per minute)							
			Rich				Lean			
			Observing	S+	S-	Mixed	Observing	S+	S-	Mixed
	PF 30 g	1	47.7	63.0	0.2	3.0	7.3	68.8	1.2	33.3
	PF 40 g	1	5.2	37.6	0.0	2.7	1.2	55.7	0.0	6.3
	PF 40 g	1	31.3	53.4	0.0	4.8	4.9	55.3	0.0	22.6
	PF 40 g	1	9.1	42.9	0.0	2.3	4.4	65.9	0.0	19.6
	EXT BL	32	58.9 (8.2)	61.3 (3.6)	0.1 (0.2)	2.2 (0.6)	4.7 (1.1)	62.5 (4.9)	0.5 (0.7)	62.7 (5.4)
	EXT	1	19.4	-	-	42.5	3.7	-	-	59.1
	EXT	1	5.3	-	-	57.6	1.3	-	-	58.9
	EXT	1	3.7	-	-	58.0	0.7	-	-	60.8
	EXT	1	0.3	-	-	51.1	0.6	-	-	60.1
	EXT	1	2.0	-	-	53.7	0.1	-	-	57.7
	FT BL	24	62.3 (4.0)	65.5 (5.2)	0.1 (0.1)	2.5 (0.9)	4.5 (0.7)	72.1 (3.8)	0.5 (0.8)	63.2 (4.3)
	FT .75	1	35.6	51.1	0.2	2.3	6.7	37.2	1.1	20.3
	FT .75	1	17.9	39.5	0.0	5.7	3.5	47.7	0.0	18.9
	FT .75	1	48.5	45.9	0.2	5.2	3.4	35.3	0.0	39.8
	FT .75	1	30.7	45.0	0.0	8.7	2.0	38.8	0.0	35.9
	FT .75	1	15.6	54.0	0.2	24.7	3.8	53.4	0.0	37.2

the finding that a fourfold difference in the rate of stimulus presentation appeared to have no effect on the resistance to change of observing. Finally, although prefeeding tended to disrupt food-key responding during the mixed schedule more in the lean component than in the rich component, responding in the lean component tended to increase when observing was placed on extinction. Thus the opposite changes in mixed-schedule food-key responding obtained with prefeeding and extinction were not associated with parallel changes in observing.

To further examine the effects of rate of conditioned reinforcement on the resistance to change of observing, Experiment 2 studied the effects of a larger difference in the rates of stimulus presentation arranged by the rich and lean components. In addition to prefeeding and extinction, the disruptive effects of ICI food deliveries were examined.

## EXPERIMENT 2

### METHOD

#### Subjects and Apparatus

The subjects and apparatus were those used in Experiment 1, with the exception of Pigeon

123. This pigeon died in the initial baseline condition of this experiment.

#### Procedure

The procedure was the same as Experiment 1 with a few modifications. The schedules of food delivery alternating with extinction were changed from RI 120-s to RI 60-s schedules in both the rich and lean components. This change was made because previous work suggested that higher rates of primary reinforcement maintain higher rates of observing (Shahan, 2002; Shahan et al., 2003). Across baseline conditions, mean obtained overall primary reinforcer rates were equal in the rich and lean components ( $M = 0.5$  reinforcers/min,  $SD = 0.2$ ), and were the same as the programmed values. In addition, the schedules of stimulus presentation in the rich and lean components were changed to RI 10-s and RI 60-s schedules. This change increased the programmed ratio of conditioned reinforcement rates from 4:1 in Experiment 1 to 6:1 in Experiment 2. Across baseline conditions, the rates of S+ presentation in the rich ( $M = 2.6$  presentations/min,  $SD = 0.3$ ) and lean ( $M = 0.4$  presentations/min,  $SD = 0.1$ ) components were near those arranged by the RI schedules

of stimulus delivery. The obtained ratio of S+ presentation rates in the rich and lean components was 7.1:1. Other details of the procedure were as in Experiment 1.

Following stabilization of observing and food-key response rates, as judged visually across at least five sessions, 5-day blocks of pre-session feeding, observing-response extinction, and ICI response-independent food deliveries were used to try to disrupt performance. In the 5-day block of pre-session feeding, 30 min before the session the pigeons were fed 20 g, 30 g, 40 g, 40 g, and 40 g of pigeon chow, in that order (cf. Nevin & Grace, 1999). After running weights were recovered and a stable baseline was reestablished, five sessions of observing-response extinction occurred as described in Experiment 1. Finally, once a stable baseline was reestablished, 2-s deliveries of the food hopper were presented during the pre-session and ICI blackouts on a fixed-time (FT) 0.75-s schedule (cf. Nevin, 1974). Nearly continuous delivery of ICI food was arranged because previous work with this procedure (Shahan et al., 2003) suggested that responding might be insensitive to a lower rate. Table 2 shows the number of sessions in each baseline before the disrupters were introduced.

### RESULTS

The top panel of Figure 3 shows observing response rates during the mixed schedule in the rich and lean components. Observing rates were invariably higher during the rich component than during the lean component and did not vary systematically across successive exposures to the baseline. As a result of observing responses, the mean (*SD*) proportions of time spent in the presence of the schedule-correlated stimuli across exposures to the baseline condition in the rich and lean components, respectively, were: 0.56 (0.04) and 0.17 (0.4) for Pigeon 77, 0.52 (0.03) and 0.13 (0.04) for Pigeon 210, and 0.57 (0.03) and 0.15 (0.04) for Pigeon 206.

The bottom panel of Figure 3 shows response rates on the food key for the rich and lean components during the mixed schedule and during S+ presentations. Response rates were higher during S+ presentations than during the mixed schedule stimuli. This difference was most pronounced in the rich component as a result of considerably lower

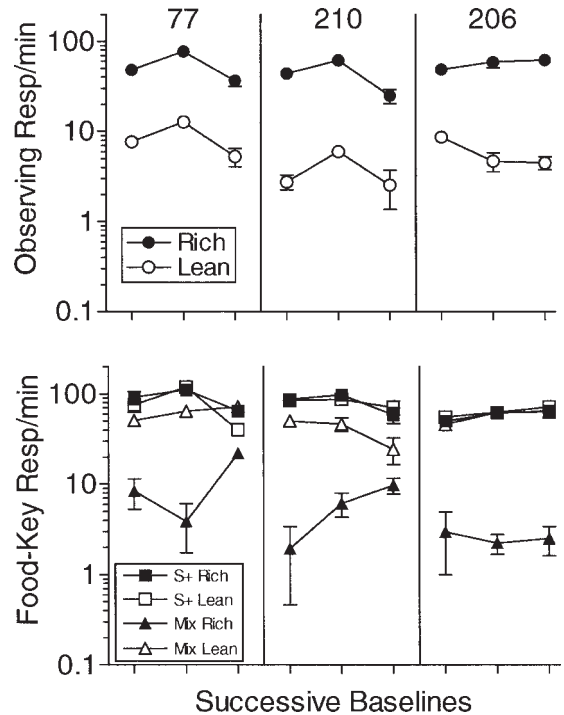


Fig. 3. Response rates in Experiment 2. The top panel shows mean observing rates in the rich and lean components across successive exposures to the baseline condition. The bottom panel shows mean food-key response rates during S+ and the mixed schedule. Means are calculated over the last five sessions of baseline prior to disruption. The y axis is logarithmic. Error bars represent  $\pm 1$  SD.

response rates during the mixed-schedule stimulus in the rich component than in the lean component. Response rates during S+ presentations did not differ systematically in the rich and lean components. Response rates during S- were always low and did not differ systematically for the rich and lean components (see Table 2). Food-key response rates did not vary systematically across the successive baselines.

Figure 4 shows resistance-to-change analyses of disruptions in responding produced by pre-session feeding, ICI FT-food deliveries, and extinction of observing responses. The analyses parallel those in Figure 2. Absolute response rates are given in Table 2. Prefeeding and ICI FT-food deliveries typically disrupted observing more than food-key responding during S+. Disruptions in food-key responding during S+ (left panels) were small and similar

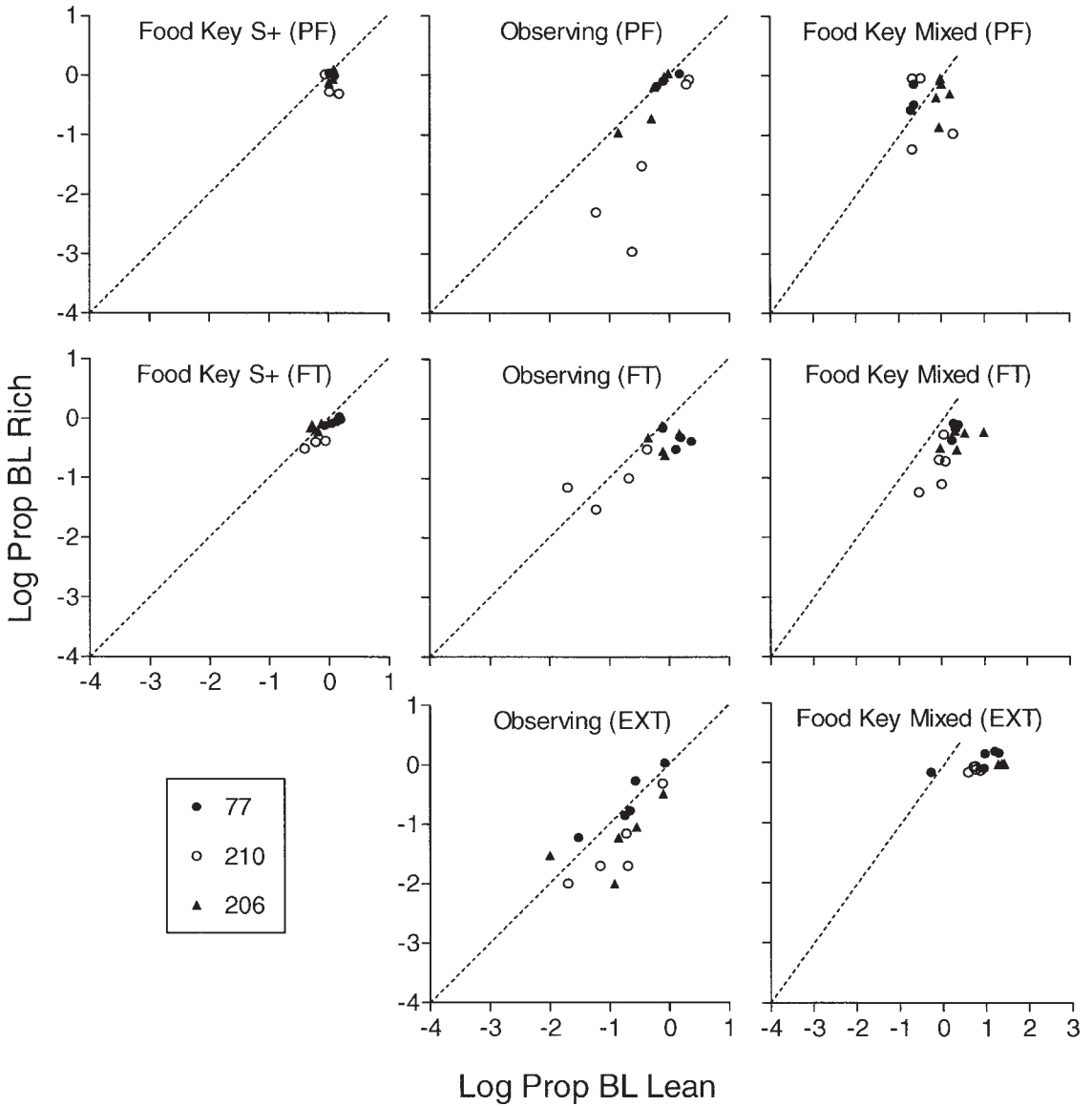


Fig. 4. Resistance-to-change analyses for Experiment 2. Log proportion of baseline in the rich component is plotted as a function of log proportion of baseline in the lean component during the disruption conditions of Experiment 2. Data from each session of each disruption condition are shown. PF, FT, and EXT refer to prefeeding, ICI FT-food, and extinction of observing.

in the rich and lean components. Data points tended to fall to the right of the major diagonal, usually because of increases in S+ responding in the lean component (i.e., log proportion of baseline greater than 0). For observing (middle panels), a majority of the data points fall to the right of the major diagonal during all three disruptors, suggest-

ing that observing was more disrupted in the rich component than in the lean component. However, this effect varied across pigeons and disruptors. For Pigeon 77, data points were reliably displaced to the right of the major diagonal only in the ICI FT-food condition, and only as a result of increases in observing in the lean component. Like observing, food-key

responding in the mixed schedule tended to decrease more during the rich component than during the lean component in the prefeeding condition. Mixed-schedule food-key responding tended to decrease in the rich component and to increase in the lean component in the ICI FT-food condition, but mostly only increased in the lean component in the extinction of observing condition.

#### DISCUSSION

Consistent with the findings of Experiment 1, observing rates were higher when observing produced more frequent schedule-correlated stimuli. Food-key response rates were similar for the rich and lean components during S+ presentations, but were higher during S+ presentations than during the mixed-schedule stimuli (Figure 3). Both of these findings also are consistent with the results of Experiment 1. Unlike Experiment 1, food-key response rates during the mixed-schedule stimuli were consistently higher in the lean component than in the rich component. This difference likely resulted from the increased divergence of observing rates in the rich and lean components and the greater exposure to the mixed-schedule stimulus in the lean component.

Despite the larger difference in rates of stimulus presentation than in Experiment 1, observing was not more resistant to change in the rich component (Figure 4). In fact, there was some tendency for observing to be more resistant to change in the lean component. Similarly, mixed-schedule food-key responding tended to decrease more in the rich component than in the lean component. Unlike observing, however, mixed-schedule food-key responding often increased in the lean component under disruption conditions.

#### GENERAL DISCUSSION

In both experiments, observing rates were higher when observing produced more frequent stimulus presentations (Figures 1 and 3). This finding suggests that higher rates of conditioned reinforcement maintain higher response rates. Similar effects have been noted with variations in the duration of the initial links of chain schedules (e.g., Ferster & Skinner, 1957), and relative rate of transition into the terminal links of concurrent-chains schedules (e.g., Baum, 1974; Davison, 1983).

Variations in the initial links of chain schedules, however, also produce changes in the rate of primary reinforcement. The use of the observing-response procedure in the present experiment permitted examination of variations in the rate of conditioned reinforcement in the absence of changes in primary reinforcement rate.

The finding that response rates varied with the conditioned reinforcement rate in the absence of differences in primary reinforcement rate is inconsistent with the way in which delay-reduction theory characterizes preference in concurrent-chains procedures. Delay-reduction theory suggests that preference in concurrent chains depends on the overall rate of primary reinforcement provided by the two options and the reduction in delay to primary reinforcement signaled by each of the terminal links (Squires & Fantino, 1971). The theory has no terms to represent independent effects of differences in rate of conditioned reinforcement and suggests that differential rates of transition into the terminal links affect choice only as a result of changes in rates of *primary* reinforcement provided by the two options. Although the present experiment did not use a concurrent-chains procedure, findings from the observing-response procedure have often been used to evaluate the predictions of delay-reduction theory (e.g., Fantino, 1977). Experiments using other procedures (Zimmerman et al., 1967), including modified concurrent-chains procedures (Mazur, 1999; Williams & Dunn, 1991), also suggest that increases in the rate of conditioned reinforcement increase responding in the absence of increases in the rate of primary reinforcement. These data provide support for models like the contextual choice model (Grace, 1994) and the hyperbolic value-added model (Mazur, 2001) that include an explicit role for conditioned reinforcement rate.

In addition to examining the effects of rate of conditioned reinforcement on rate of observing, the present experiments examined the effects of rate of conditioned reinforcement on the resistance to change of observing. Despite higher rates of conditioned reinforcement and higher rates of observing in the rich than in the lean component, resistance to change was not greater in the rich component. This outcome is inconsistent with the robust finding that higher rates of primary reinforce-

ment produce greater resistance to change (e.g., Nevin & Grace, 2000). This finding may be interpreted in three ways.

First, the lack of differential resistance to change in the two components could reflect some procedural artifact. The procedure and experimental parameters, however, were similar to those used by Shahan et al. (2003) to show the effects of different rates of primary reinforcement on the resistance to change of observing. In addition, the experimental manipulation was not without effect. Differences in rate of conditioned reinforcement were potent enough to produce reliable differences in observing rate. One potential concern is that response-rate decreases in the lean component were constrained by a possible floor effect. A floor effect seems unlikely in Experiment 1, because the decreases in observing rates were large in many conditions and of approximately equal size in the rich and lean components. A floor effect could be more of a concern in Experiment 2 where observing rates tended to be lower in the lean component than in Experiment 1. In addition, observing in the lean component tended to be less disrupted than in the rich component. Despite this tendency, the reductions in observing rates often were large for both components. For example, in the extinction condition (Figure 4, bottom center), observing for all 3 pigeons sometimes decreased by nearly two log units in both components. These decreases should have allowed disruptions to be greater in the lean component. Thus the lack of differential resistance to change in the two components likely was not due to a floor effect in the lean component.

If the greater resistance to change of observing in the lean component in Experiment 2 is not the result of a floor effect, then the source of this counterintuitive finding remains unknown. One possible explanation emerges when we consider food-delivery rates for the mixed schedule. In Experiment 2, food-key response rates during the mixed schedule were low in the rich component (see Figure 3), and they likely reflect the large allocation of responding in the mixed-schedule to the observing key and the resultant smaller amount of time spent in the presence of the mixed-schedule stimulus. The top panel of Figure 5 shows the effects of these low response rates on the rate of primary

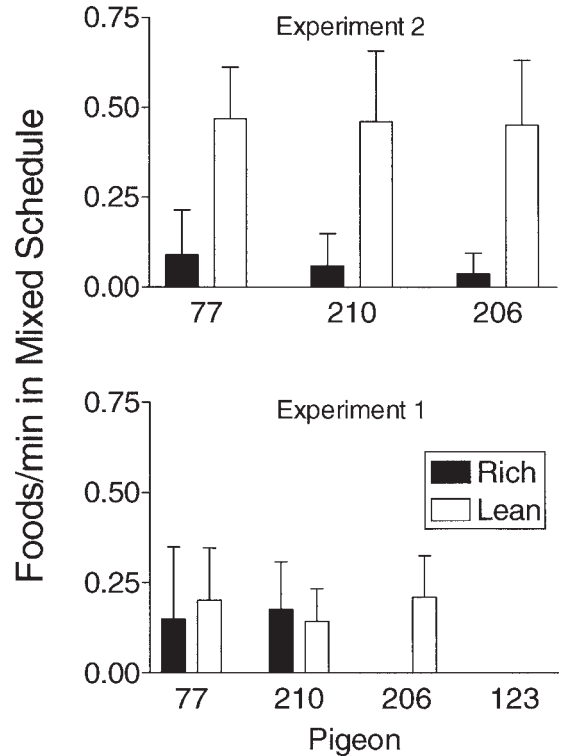


Fig. 5. Reinforcer rates during the mixed schedule in Experiments 1 and 2. The top panel shows mean number of food presentations per minute during the last five sessions of baseline prior to disruption in the rich and lean components in Experiment 2. The bottom panel shows the same measures during Experiment 1. Error bars represent  $\pm 1$  SD.

reinforcement in the mixed schedule in Experiment 2. Food delivery rates in the mixed schedule were higher in the lean component than in the rich component. Nonetheless, these lower rates of food delivery in the mixed schedule for the rich component do not reflect a lower *overall* rate of food delivery in that component, but merely a redistribution of food deliveries to S+ periods. Across pigeons, an average of 8% and 87% of food deliveries were obtained in the mixed-schedule in the rich and lean components, respectively. If the resistance to change of observing depended on the rate of primary reinforcement delivered in the context in which observing was occurring (i.e., the mixed-schedule stimuli), then observing might be expected to be more resistant to change in the lean component. Thus the differential rates of primary reinforcement in the mixed schedule might explain the finding that observing tended to

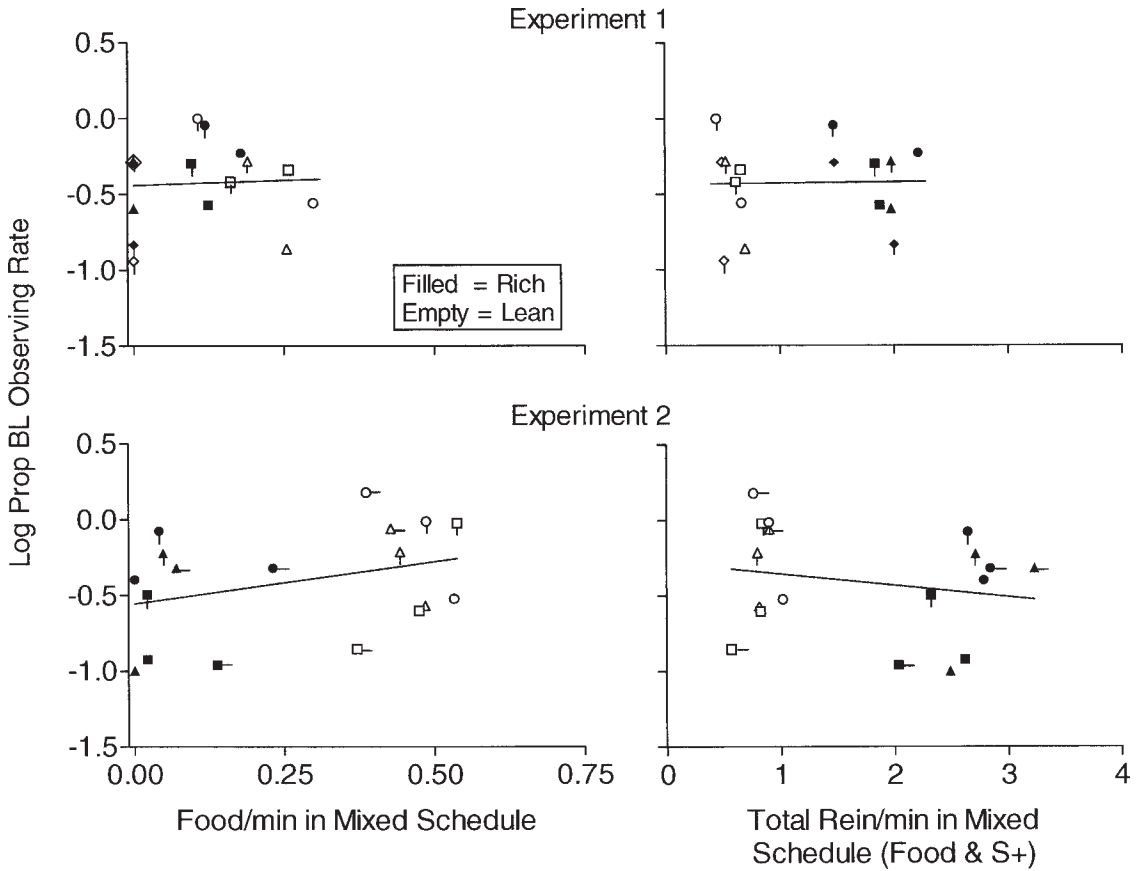


Fig. 6. Resistance to change as a function of reinforcer rate in the mixed schedule. The left panels show log proportion of baseline observing rate as a function of the rate of food delivery in the mixed schedule. The right panels show log proportion of baseline observing rate as a function of the combined rate of food and S+ delivery. Filled symbols represent data from the rich component and empty symbols data from the lean component. Pigeons 77, 210, 206, and 123 are represented by circles, squares, triangles, and diamonds, respectively. Symbols with vertical lines, horizontal lines, and no lines represent data from the prefeeding, ICI FT-food, and extinction of observing conditions, respectively. Fitted lines represent least squares linear regressions. Each data point represents the mean of the 5 days of each disruption condition.

be more resistant to change in the lean component in Experiment 2.

If rates of primary reinforcement were similarly higher in the mixed schedule of the lean component in Experiment 1, then this difference in rates of primary reinforcement could have counteracted the effects of the lower rate of conditioned reinforcement on the resistance to change of observing in that component. As in Experiment 2, a higher proportion of food deliveries were obtained in the mixed schedule in the lean component (i.e., 60%) than in the rich component (i.e., 17%). The bottom panel of Figure 5 shows, however, that there was no consistent difference in the average rates of food delivery in

the mixed schedule for the rich and lean components in Experiment 1. The data from Pigeon 123 are especially interesting because this pigeon earned no food deliveries during the mixed schedule and showed no difference in resistance to change of observing (Figure 2). Thus differential rates of primary reinforcement in the two components during the mixed schedule cannot explain the absence of a difference in resistance to change for this pigeon.

Figure 6 further assesses the role of reinforcement rates in the mixed schedule on the resistance to change of observing. The left panels show log proportion of baseline observing rate as a function of baseline rate of food

delivery in the mixed schedule. The right panels show log proportion of baseline observing rate as a function of the combined rate of food delivery and S+ presentation in the mixed schedule. In Experiment 1 (top panels), the resistance to change of observing was unrelated to both the rate of food delivery in the mixed schedule and the combined reinforcement rate. In Experiment 2 (bottom panels), there was a large and consistent difference in food delivery rates in the rich and lean components, and resistance to change of observing was positively related to increases in food delivery rate in the mixed schedule. In contrast, the resistance to change of observing decreased with increases in the combined rate of reinforcement. Thus only the difference in mixed-schedule food delivery rates might account for the greater resistance to change of observing in the lean component in Experiment 2, and no such difference can account for the lack of difference in resistance to change of observing in Experiment 1. Despite the approximate fourfold or sixfold difference in S+ presentation rates in Experiments 1 and 2, resistance to change of observing only differed when rates of food delivery during the mixed schedule differed. Thus Figure 6 further supports the conclusion that rates of conditioned reinforcement had no effect on the resistance to change of observing.

Although the baseline rate of food delivery during the mixed schedule had no effect on resistance to change of observing in Experiment 1, it is possible that changes in the rate of primary reinforcement in the mixed-schedule under the disruption conditions disproportionately affected observing in the rich component. For example, decreases in observing produced by the introduction of a disruptor might have led to an increase in the rate of food delivery in the mixed schedule. Such increases in food delivery rates might have been greater for the rich component, thereby resulting in greater competition between observing and food-key responding and greater disruptions in observing in that component. Figure 7 shows resistance to change of observing as a function of changes in mixed-schedule food rates during the disruption conditions. In Experiment 1 (top panel), rates of food delivery in the mixed schedule changed little and unsystematically for the

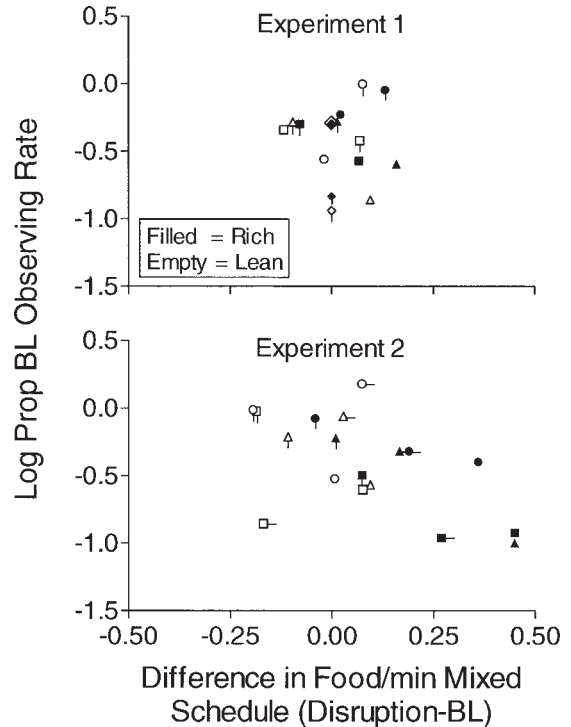


Fig. 7. Log proportion of baseline observing rate as a function of the difference between food delivery rate in the mixed schedule under disruption conditions and under baseline conditions. Values greater than zero represent increases in the rate of food delivery under disruption conditions; values less than zero represent decreases in the rate of food delivery under disruption conditions. Data are shown as in Figure 6.

rich and lean components. In addition, there was no relation between the resistance to change of observing and the change in food delivery rate under disruption conditions. In Experiment 2 (bottom panel), the rate of food delivery tended to increase under disruption conditions in the rich component and to remain roughly unchanged or decrease in the lean component. The resistance to change of observing typically was higher when the rate of food delivery decreased during disruption and was lower when the rate of food delivery increased in the mixed schedule. Thus increases in the rate of food delivery in the mixed schedule may have contributed further to the lower resistance to change of observing in the rich component in Experiment 2, but did not contribute to the nondifferential resistance to change in Experiment 1.

A second interpretation of the present results is that higher rates of stimulus

production may not have generated greater resistance to change because the stimuli have their effects on response rates through some mechanism other than strengthening by reinforcement. For example, Schuster (1969) demonstrated that, although stimuli associated with the delivery of primary reinforcers may increase response rates, these rate increases may not be the result of the hedonic effects of the stimuli. In one set of experiments, Schuster found that adding response-dependent presentations of a stimulus paired with reinforcer delivery to one component of a multiple variable-interval (VI) VI schedule increased response rates in that component. Nonetheless, the added stimulus presentations did not produce contrast in the other component, as would be expected if reinforcers had been added to the component. In a second set of experiments, Schuster found that, even though adding response-dependent presentations of a stimulus paired with reinforcer delivery to one terminal link of a concurrent-chains procedure increased response rates in that terminal link, responding in the initial links revealed a preference for the terminal link *without* the added stimulus presentations. Thus Schuster suggested that the higher response rates obtained with the added stimuli were not a result of the hedonic value of the stimuli.

Although the source of the response rate increases in Schuster's experiments is unclear, various information-based mechanisms have been proffered as alternatives to an account of apparent conditioned reinforcement effects based on the hedonic effects of the stimuli (e.g., Baum, 1973; Bolles, 1975; Hendry, 1969; Schuster, 1969). Although consideration of the adequacy of these accounts is beyond the scope of the present discussion, the results of the present experiments are, nonetheless, consistent with Schuster's data. Increases in the rate of stimulus presentation increased the rate of observing but did not increase the resistance to change of observing. If resistance to change is accepted as a more appropriate measure of response strength than response rates, then the present experiments suggest that increases in the rate of stimulus presentation did not increase response strength. If the stimulus presentations had hedonic value of their own and were acting as conditioned reinforcers, then an increase in their

frequency would have been expected to increase response strength. On the contrary, the only trend toward a difference in response strength for the two components was for observing to be less resistant to change in the component with the higher rate of stimulus presentation. This outcome would be expected based on Schuster's concurrent-chains data and the finding that preference and resistance to change are generally positively related (Grace & Nevin, 1997). Given the potential impact of differences in mixed-schedule rates of primary reinforcement on resistance to change of observing in Experiment 2, this apparent correspondence of results must be approached cautiously. Nonetheless, future research might usefully combine procedures similar to those used by Schuster and those of Grace and Nevin to examine the effects of added stimulus presentations on preference and resistance to change. Such research would permit an evaluation of the generality of the present results and might avoid some of the complexities introduced by the observing-response procedure.

A third potential interpretation of the present results is that food-associated stimuli do function as reinforcers, but that behavioral-momentum theory is not readily applicable to parameters of conditioned reinforcement. Resistance to change appears to be largely governed by the overall Pavlovian stimulus-reinforcer relation (e.g., Nevin, Tota, Torquato, & Shull, 1990). The lack of effect of conditioned reinforcement rate on resistance to change could reflect the higher-order conditioning required for the conditioned reinforcers to produce an improvement in the stimulus-reinforcer relation when the rate of primary reinforcement remains constant—that is, because the conditioned reinforcers may themselves be the result of a Pavlovian conditioning process, any transfer of value to the overall Pavlovian stimulus-reinforcer context would require second-order Pavlovian conditioning. The extent to which such second-order conditioning should be expected in the present procedure is unclear. As noted by Williams and Dunn (1991), a similar potential failure of higher-order conditioning in Schuster's (1969) experiments could help to explain why imbedding additional food-associated stimuli in a terminal link failed to produce an increase in value of that terminal

link. Given that (a) resistance to change depends on the overall Pavlovian stimulus-reinforcer relation, (b) the present results reflect a lack of transfer of value from conditioned reinforcers to the overall stimulus-reinforcer context because of a failure of second-order conditioning, and (c) such failures of second-order conditioning prove common in a variety of procedures, then behavioral-momentum theory might have limited applicability to parameters of conditioned reinforcement.

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