*DIFFERENCES IN THE EFFECT OF PAVLOVIAN CONTINGENCIES UPON
BEHAVIORAL MOMENTUM USING AUDITORY VERSUS VISUAL STIMULI*

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We examined the role of Pavlovian and operant relations in behavioral momentum by arranging response-contingent alternative reinforcement in one component of a three-component multiple concurrent schedule with rats. This permitted the simultaneous arranging of different response-reinforcer (operant) and stimulus-reinforcer (Pavlovian) contingencies during three baseline conditions. Auditory or visual stimuli were used as discriminative stimuli within the multiple concurrent schedules. Resistance to change of a target response was assessed during a single session of extinction following each baseline condition. The rate of the target response during baseline varied inversely with the rate of response-contingent reinforcement derived from a concurrent source, regardless of whether the discriminative stimuli were auditory or visual. Resistance to change of the target response, however, did depend on the discriminative-stimulus modality. Resistance to change in the presence of visual stimuli was a positive function of the Pavlovian contingencies, whereas resistance to change was unrelated to either the operant or Pavlovian contingencies when the discriminative stimuli were auditory. Stimulus salience may be a factor in determining the differences in resistance to change across sensory modalities.

Key words: behavioral momentum, resistance to extinction, alternative reinforcement, multiple concurrent schedules, salience, lever press, rats

Physicists use the concept of momentum to describe physical bodies in motion across space. Momentum is equal to the product of mass and velocity. Thus, two bodies in motion with equal velocity and mass are equivalent in momentum. Any deviation from equality across either mass or velocity implies a difference in momentum. For example, the heavier of two objects traveling with equal velocity will have greater momentum, as assessed by applying equal force to the two objects and observing less change in the velocity of the heavier object.

Nevin, Mandell, and Atak (1983) suggest that the physicist's view of momentum may be metaphorically extended to an analysis of both steady-state and transition-state performance. Behavior, like a body in motion, has momentum. Response rate is seen as analogous to velocity, whereas behavior's resistance to change is equated with mass. These investigators used pigeons as subjects in a two-component multiple schedule in which they parametrically varied the reinforcement rates

across components. They found that if a force (e.g., extinction or satiation) is applied across situations involving high versus low reinforcement rate, resistance to change (behavioral mass) is greater in the situation correlated with the higher rate of reinforcement.

Cohen (1986) and Cohen, Riley, and Weigle (1993) used rats as subjects in their momentum studies and also observed that resistance to change was greater in the situation associated with the higher density of reinforcement. These authors also defined particular boundaries to the behavioral momentum effect. For example, Cohen (1986) demonstrated that drugs such as *d*-amphetamine sulfate, haloperidol, sodium pentobarbital, and CCK8 do not operate as other response disrupters (e.g., extinction and food satiation) in showing differences in resistance to change across situations correlated with different rates of reinforcement. In addition, Cohen et al. (1993) did not find a relationship between resistance to change and reinforcement density when the reinforcement rates were varied between blocks of training sessions, but they did find a relationship when different rates of reinforcement were correlated with different discriminative stimuli and alternated within sessions (a multiple schedule).

Although it was shown that differences in re-

The authors thank John A. Nevin for his assistance in the development of this research. We also thank Philip J. Bersh for his helpful comments on an earlier version of this manuscript.

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inforcement rate affect behavioral persistence, the question remained whether this effect could be attributed to stimulus-reinforcer (Pavlovian) or response-reinforcer (operant) relations. Nevin, Tota, Torquato, and Shull (1990) conducted two experiments with pigeons and showed that the effect of contingent and noncontingent alternative reinforcement upon behavioral persistence was attributable to Pavlovian contingencies. In Experiment 1, they provided noncontingent reinforcement in one component of a two-component multiple schedule with equal variable-interval (VI) schedules operative across components. Extinction and satiation tests were conducted, and they found that resistance to change was greater in the component associated with the noncontingent alternative reinforcement (i.e., in the component with the stronger stimulus-reinforcer relation).

In Experiment 2, Nevin et al. (1990) arranged contingent alternative reinforcement within a three-component multiple concurrent schedule. In the first component (A), the concurrent reinforcement rates were 45 and 15 food reinforcers per hour for a left and right key peck, respectively. Thus, there were a total of 60 reinforcers per hour signaled by the stimuli correlated with Component A. In the second (B) and third (C) components, extinction was arranged on the left key. Pecks on the right key produced 15 reinforcers per hour during Component B, but resulted in 60 reinforcers per hour during Component C. The resistance to change of right-key responding, assessed by extinction and satiation tests, was greater in the two components associated with 60 reinforcers per hour (Components A and C) than in the component correlated with 15 reinforcers per hour (Component B). Resistance to change was about the same in Components A and C, despite the different rates of reinforcement for right-key responding. Thus, the persistence of a response in the presence of a stimulus depended more on the stimulus-reinforcer (Pavlovian) than on the response-reinforcer (operant) relation.

The demonstration of a momentum effect with rats prompted the current investigation on the possible role of Pavlovian contingencies in determining resistance to change. Although several researchers (Nevin, 1984; Nevin et al., 1990) have carefully studied this

issue with pigeons, no one has directly examined it using rats as subjects. Therefore, the present experiment studied the effect of alternative reinforcement upon behavioral momentum with rats using a procedure similar to Experiment 2 of Nevin et al. (1990). In addition, this experiment examined the role of auditory versus visual discriminative stimuli within the multiple concurrent schedule. The question was whether the effect of Pavlovian contingencies on resistance to change would differ depending on the use of discriminative stimuli that were either auditory or visual.

METHOD

Subjects

Eight experimentally naive male Charles River CD rats (MV-24 to MV-31) were used in this experiment. The rats were housed singly and were maintained at 80% of their free-feeding weights through postsession feeding. Water was always available in each animal's home cage. The rats were between 2 to 4 months old at the start of the experiment.

Apparatus

Experimental sessions were conducted in four BRS/LVE two-lever rat operant chambers (Model RTC-022). The left and right levers protruded 2.2 cm into the chamber from the right wall (operant panel), and each lever required a minimum force of 0.15 N to operate. A bank of three jewel lights was located 4.3 cm above each lever. Only the center lights of each bank were used as visual stimuli. Both center lights were operated simultaneously, and visual stimuli were provided by either continuous or flickering (50% duty cycle) illumination of these lights at a rate of 1 flicker per second (f/s) or 5 f/s. A houselight was centered on the operant panel 1.5 cm from the ceiling and 1.5 cm below it was a Sonalert providing a 90-dB low-frequency tone. A second Sonalert was placed 3.5 cm from the ceiling centered along the left wall and provided a 94-dB high-frequency pulsing tone (1 pulse per second, p/s). An 88-dB pulsing buzzer (5 p/s) was placed on the top of the chamber next to a 3.3-cm hole centered on the ceiling. An automatic food dispenser delivered 45-mg Noyes pellets to a

Multiple Concurrent Schedule					
	Discriminative Stimuli		Reinforcement Rate		
	Visual	Auditory	Foods/Hr	Foods/Hr	Overall Foods/Hr
Component 1	Constant	Low Tone	96	24	120
Component 2	1 fps	High Tone	0	24	24
Component 3	5 fps	Buzzer	0	120	120
			Left Lever	Right Lever	

Fig. 1. This diagram shows the programmed rates of reinforcement contingent on a left or right (target) response across the three components of the multiple concurrent schedule. Also shown is the overall rate of food reinforcement, irrespective of its source, signaled by the discriminative stimuli associated with each of the three components.

scoop-type chute centered on the operant panel 1.2 cm above the grid floor.

The experimental chambers were placed in MED Associates sound- and light-attenuating enclosures (Model ENV-015M). Further sound attenuation was provided by a ventilation fan and masking noise produced by a Grason-Stadler noise generator (Model 901B). A WYSE 80286 computer, using MED Associates Notation, was used to program stimuli and record responses through a MED Associates interface.

Procedure

Preliminary training. Differential reinforcement of successive approximations (shaping) was used to establish lever-press responding. Shaping and 3 days of continuous reinforcement (CRF) were programmed on the left lever followed by shaping and 3 days of CRF on the right lever. This was followed by a series of concurrent VI VI schedules. The schedule values were concurrent VI 10 s VI 10 s, VI 30 s VI 30 s, VI 60 s VI 60 s, VI 45 s VI 120 s, and VI 120 s VI 45 s. The rats' relative rates of responding tracked the relative rates of reinforcement.

Baseline and extinction tests. Experimental sessions were conducted 5 days per week. The basic design involved three alternations between baseline and extinction test conditions. Experimental sessions during baselines consisted of three cycles of a three-component multiple concurrent schedule. Each component was 6 min in duration, and the components were presented quasi-randomly (with-

out replacement) within a session. The houselight was illuminated throughout the session only when auditory stimuli were used. These components were separated by a 30-s intercomponent period without any experimentally programmed events other than the houselight (where applicable). Thus, each cycle lasted 19.5 min and the total session length during baseline conditions equaled 58.5 min. The signaling of the components was by one of three different auditory stimuli or one of three different visual stimuli, depending upon the experimental condition in effect (see below).

Figure 1 illustrates the arrangement of concurrent reinforcement during baseline conditions across the three components of the multiple concurrent schedule. A single VI 30-s schedule operated continuously throughout the session and arranged reinforcers for either a left or right lever press through a probability (*p*) gate. In Component 1, the programmed reinforcement rate was 96 food pellets per hour on the left lever (*p* = .8) and 24 food pellets per hour on the right lever (*p* = .2). During Components 2 and 3, extinction was arranged on the left lever (*p* = 0). The right lever yielded a programmed reinforcement rate of 24 food pellets per hour (*p* = .2) during Component 2 and 120 food pellets per hour (*p* = 1.0) in Component 3. Reinforcers programmed but not collected by the end of a component were canceled. Reinforcers arranged during the intercomponent periods were canceled.

A single extinction test session followed

Table 1
Order of conditions and correlated component stimuli.

Condition	Component 1	Component 2	Component 3
Baseline 1	Low tone	High tone (1 p/s)	Buzzer (5 p/s)
Extinction 1	Low tone	High tone (1 p/s)	Buzzer (5 p/s)
Baseline 2			
Initial phase	Low tone + light	High tone (1 p/s) + light (1 f/s)	Buzzer (5 p/s) + light (5 f/s)
Terminal phase	Light	Light (1 f/s)	Light (5 f/s)
Extinction 2	Light	Light (1 f/s)	Light (5 f/s)
Baseline 3			
Initial phase	Light + low tone	Light (1 f/s) + high tone (1 p/s)	Light (5 f/s) + buzzer (5 p/s)
Terminal phase	Low tone	High tone (1 p/s)	Buzzer (5 p/s)
Extinction 3	Low tone	High tone (1 p/s)	Buzzer (5 p/s)

Note. p/s, pulse per second; f/s, flicker per second.

each of the baseline conditions. These extinction tests employed the same multiple concurrent schedule described in baseline, except that the food reinforcement was discontinued for a single session. Another procedural difference arranged during extinction tests was the presentation of the components quasi-randomly within blocks of three components instead of being presented quasi-randomly across the session. This procedural change was introduced to control for differences in resistance to change across components being attributable merely to the ordering of the components across extinction. The extinction session ended upon completion of the block in which the rat's elapsed time without a response on either lever exceeded 12 min. Data were recorded at the end of each 19.5-min block (Components 1, 2 and 3 presented once per block) including all responses emitted during the final

block in which the extinction criterion was met.

Correlated component stimuli. Table 1 shows the sequence of experimental conditions along with the exteroceptive stimuli correlated with each component during a particular condition. During Baseline 1 and Extinction 1, three different auditory stimuli were separately correlated with each of the three components of the multiple concurrent schedule. In order to facilitate the transfer of stimulus control, the visual stimuli were placed in compound with the auditory stimuli during the initial phase of Baseline 2. This stimulus compound remained in place until steady-state target responding was identified by visual examination (5-day minimum). The visual stimuli were subsequently presented alone during the terminal phase of Baseline 2 as well as during Extinction 2. The same stimulus compound as in the initial phase of Baseline 2 was reintroduced during the initial phase of Baseline 3. Once steady-state target responding was recovered, the auditory stimuli were presented alone during the terminal phase of Baseline 3 as well as during Extinction 3. Target response rates during the terminal phase of each baseline condition were judged to be stable by visual examination (5-day minimum) before the corresponding extinction test was performed. The number of daily sessions conducted during each baseline condition (initial and terminal phases) are indicated in Table 2.

RESULTS

Tables 3, 4, and 5 show the absolute response rates and relative response rates av-

Table 2

Number of daily sessions for the three baseline conditions (all subjects).

Rat	Baseline 1			Baseline 2			Baseline 3		
	Ini-	Ter-	Total	Ini-	Ter-	Total	Ini-	Ter-	Total
	tial	min-		tial	min-		tial	min-	
MV-24		al	43		al	22		al	12
MV-25			26			22			16
MV-26			61			12			12
MV-27			61			17			13
MV-28			26			31			26
MV-29			41			21			16
MV-30			33			21			12
MV-31			25			21			17

Table 3
Response rate, reinforcement rate, and relative measures for Baseline 1.

Rat	Response rate (min)		Reinforcement rate (hr)			Relative	
	Left	Right	Left	Right	Total	Responses	Reinforcers
Component 1							
MV-24	17.98 (1.58)	10.31 (0.58)	91.33	28.00	117.33	.37	.24
MV-25	25.50 (1.20)	15.00 (1.01)	90.00	24.67	114.67	.37	.21
MV-26	31.19 (0.88)	6.66 (0.74)	102.00	15.33	117.33	.17	.13
MV-27	9.63 (0.42)	3.18 (0.73)	90.67	21.33	112.00	.24	.19
MV-28	24.94 (2.50)	13.41 (0.80)	90.00	26.00	116.00	.35	.22
MV-29	17.82 (2.18)	9.81 (1.58)	92.67	22.67	115.33	.35	.19
MV-30	19.91 (1.63)	15.70 (0.63)	98.00	18.67	116.67	.44	.16
MV-31	27.16 (1.73)	9.43 (0.92)	95.33	21.67	117.00	.26	.23
Component 2							
MV-24	2.97 (0.61)	10.78 (0.40)		22.67	22.67	.79	1.00
MV-25	3.44 (0.95)	15.79 (1.17)		24.00	24.00	.82	1.00
MV-26	0.87 (0.35)	25.64 (1.91)		24.00	24.00	.97	1.00
MV-27	0.35 (0.08)	8.37 (1.14)		20.67	20.67	.96	1.00
MV-28	2.96 (0.46)	19.06 (2.2)		23.33	23.33	.86	1.00
MV-29	4.46 (0.66)	10.70 (0.44)		21.33	21.33	.71	1.00
MV-30	2.84 (0.28)	21.20 (1.84)		24.67	24.67	.88	1.00
MV-31	1.94 (0.55)	14.58 (1.84)		21.33	21.33	.89	1.00
Component 3							
MV-24	6.32 (1.32)	17.89 (0.49)		110.67	110.67	.75	1.00
MV-25	3.39 (0.87)	41.14 (0.96)		111.33	111.33	.88	1.00
MV-26	3.99 (0.55)	14.27 (0.89)		116.67	116.67	.78	1.00
MV-27	2.85 (0.11)	8.89 (1.11)		106.00	106.00	.75	1.00
MV-28	10.57 (1.63)	30.11 (2.31)		116.00	116.00	.74	1.00
MV-29	7.73 (0.63)	19.56 (1.41)		110.67	110.67	.72	1.00
MV-30	3.60 (0.81)	25.30 (2.01)		115.33	115.33	.85	1.00
MV-31	6.32 (1.19)	24.48 (0.50)		116.67	116.67	.80	1.00

Note. Standard errors are shown in parentheses for response rate only.

eraged across the last 5 days for each of the three baseline conditions. Response rates on the left lever were highest during Component 1 (96 pellets per hour), whereas response rates on the right lever (target response) were highest during Component 3 (120 pellets per hour). A comparison of target response rates between Components 1 and 2 showed that the target response rates were generally lower during the component that arranged response-contingent alternative reinforcement (i.e., Component 1). The relative rate of the target response deviated from the relative rates of reinforcement in the direction of indifference for all components and for all animals. These findings for target responding during baseline conditions are consistent with those reported by Nevin et al. (1990, Experiment 2) on the influences of absolute and relative reinforcement schedules.

Tables 3, 4, and 5 also show the obtained

reinforcement rates and relative reinforcer measures averaged across the last 5 days of each of the three baseline conditions. The obtained rates of reinforcement across the three baselines approximated the programmed reinforcement rates. The rate of reinforcement obtained from the right (target) lever during Components 1 and 2 were similar. Likewise, the total reinforcement rate during Component 1 was similar to the total rate of reinforcement obtained during Component 3, suggesting consistent experimental control over the obtained and relative rates of reinforcement.

The left column of graphs in Figure 2 show the rate of the target response in the presence of each of the three auditory stimuli during Extinction 1 (19.5-min blocks). The y axis (target response rate) is plotted logarithmically; thus vertical distance shows relative change, and a comparison of the slopes of the functions indicates relative resistance to

Table 4
Response rate, reinforcement rate, and relative measures for Baseline 2.

Rat	Response rate (min)		Reinforcement rate (hr)			Relative	
	Left	Right	Left	Right	Total	Responses	Reinforcers
Component 1							
MV-24	16.90 (1.06)	5.48 (0.32)	88.66	21.33	110.00	.25	.19
MV-25	19.17 (0.95)	15.43 (0.75)	90.00	24.00	114.00	.41	.27
MV-26	29.21 (2.01)	13.29 (1.60)	88.00	24.00	114.00	.31	.22
MV-27	7.62 (0.89)	3.66 (0.31)	81.33	21.33	102.66	.33	.21
MV-28	31.60 (1.78)	13.94 (1.54)	90.67	27.33	118.00	.30	.23
MV-29	10.03 (1.51)	10.60 (0.59)	81.33	27.33	108.66	.51	.25
MV-30	14.53 (0.55)	18.42 (1.57)	90.67	19.33	110.00	.56	.18
MV-31	20.79 (0.68)	16.59 (1.90)	83.33	30.00	113.33	.44	.27
Component 2							
MV-24	5.21 (1.01)	8.17 (0.30)		26.00	26.00	.61	1.00
MV-25	6.39 (0.79)	16.96 (1.66)		26.67	26.67	.70	1.00
MV-26	10.98 (1.58)	26.15 (1.70)		28.67	28.67	.71	1.00
MV-27	2.29 (0.45)	6.53 (0.42)		22.00	22.00	.75	1.00
MV-28	15.76 (1.45)	29.66 (2.92)		23.33	23.33	.68	1.00
MV-29	4.10 (0.47)	9.55 (1.01)		24.00	24.00	.70	1.00
MV-30	4.31 (0.92)	21.44 (2.29)		22.00	22.00	.84	1.00
MV-31	5.58 (0.91)	15.05 (1.42)		25.33	25.33	.74	1.00
Component 3							
MV-24	3.63 (0.32)	10.24 (0.66)		109.33	109.33	.74	1.00
MV-25	2.00 (0.39)	39.27 (2.33)		115.33	115.33	.87	1.00
MV-26	12.64 (1.41)	21.99 (1.82)		113.33	113.33	.63	1.00
MV-27	2.20 (0.36)	5.68 (0.56)		105.33	105.33	.58	1.00
MV-28	13.48 (1.89)	27.95 (2.77)		113.33	113.33	.66	1.00
MV-29	3.41 (0.38)	12.09 (0.43)		106.00	106.00	.78	1.00
MV-30	3.64 (0.91)	26.78 (1.62)		123.33	123.33	.88	1.00
MV-31	5.36 (0.47)	28.58 (0.74)		113.33	113.33	.84	1.00

Note. Standard errors are shown in parentheses for response rate only.

extinction for the target response across the three components of the multiple concurrent schedule. There were no systematic differences among the slopes when reinforcement was discontinued in the presence of the three auditory stimuli.

In contrast, when the visual stimuli signaled the three components during Extinction 2 (center column, Figure 2), systematic differences in the slopes of the resistance-to-change functions emerged. For all animals, response rates were about equally resistant to extinction in Components 1 and 3 and least resistant to extinction in Component 2. This effect was clearest for Rats MV-25, MV-30 and MV-31. The magnitude of these effects appears at least as large as that obtained by Nevin et al. (1990, Experiment 2).

In order to verify that the visual stimuli were necessary for the differential resistances to extinction, the auditory stimuli were re-introduced as correlated component stimuli

during Baseline 3 and Extinction 3. As was true of the first extinction test (left column, Figure 2), response rates declined similarly in the presence of the three auditory stimuli during Extinction 3 (right column, Figure 2). In several instances, the ordering of resistance to change across the three components observed during Extinction 1 was also observed during Extinction 3.

Linear regression analysis was performed on the log target response rates across baseline and blocks of extinction for each rat during Extinction 1, 2, and 3. The individual slopes, intercepts, and coefficients of determination (r^2) are shown in Table 6. Differences in resistance to change are revealed as differences in the magnitude of the negative slope values. The greater the negative slope value, the lesser the resistance to change. During Extinction 1 and 3 (auditory stimuli), the negative slope values were less during Component 2 compared to either Component 1 or Component 3.

Table 5
Response rate, reinforcement rate, and relative measures for Baseline 3.

Rat	Response rate (min)		Reinforcement rate (hr)			Relative	
	Left	Right	Left	Right	Total	Responses	Reinforcers
Component 1							
MV-24	15.38 (1.29)	5.96 (0.15)	83.33	24.67	108.00	.28	.23
MV-25	44.95 (1.67)	11.27 (0.71)	92.67	24.00	116.67	.20	.21
MV-26	32.69 (1.70)	6.52 (0.35)	98.67	19.33	118.00	.17	.18
MV-27	6.61 (0.49)	2.26 (0.30)	84.00	23.33	107.33	.25	.17
MV-28	27.97 (2.06)	7.88 (0.54)	96.00	21.33	117.33	.22	.18
MV-29	12.52 (0.54)	6.90 (0.25)	86.00	22.67	108.67	.36	.21
MV-30	14.07 (0.85)	13.46 (0.95)	92.00	26.00	118.00	.49	.22
MV-31	29.42 (3.47)	13.81 (1.54)	94.67	22.67	117.34	.33	.20
Component 2							
MV-24	3.41 (0.71)	9.28 (0.52)		22.00	22.00	.74	1.00
MV-25	4.78 (0.71)	13.02 (1.09)		21.33	21.33	.73	1.00
MV-26	2.20 (0.34)	29.77 (0.95)		24.67	24.67	.93	1.00
MV-27	0.28 (0.08)	7.97 (0.51)		26.67	26.67	.97	1.00
MV-28	3.19 (0.71)	22.93 (1.05)		28.67	28.67	.88	1.00
MV-29	2.53 (0.57)	7.57 (0.84)		28.00	28.00	.75	1.00
MV-30	2.14 (0.14)	16.89 (0.50)		23.33	23.33	.89	1.00
MV-31	2.90 (0.77)	10.61 (2.14)		21.33	21.33	.74	1.00
Component 3							
MV-24	3.19 (0.23)	10.72 (0.31)		116.00	116.00	.80	1.00
MV-25	5.13 (0.39)	39.05 (1.74)		116.00	116.00	.88	1.00
MV-26	3.82 (0.83)	17.04 (0.78)		108.00	108.00	.82	1.00
MV-27	1.70 (0.24)	10.10 (1.05)		110.00	110.00	.86	1.00
MV-28	8.42 (1.06)	28.05 (2.23)		111.33	111.33	.77	1.00
MV-29	4.03 (0.80)	11.97 (0.74)		111.33	111.33	.76	1.00
MV-30	1.57 (0.34)	23.80 (0.61)		122.67	122.67	.94	1.00
MV-31	6.48 (1.17)	27.90 (1.34)		115.33	115.33	.84	1.00

Note. Standard errors are shown in parentheses for response rate only.

nent 1 or 3 for most subjects. In contrast, when visual stimuli were used during Extinction 2, the negative slope values were reliably larger for Component 2 relative to either Component 1 or 3 for all subjects. Moreover, the negative slope values were similar across Components 1 and 3 for all subjects when the discriminative stimuli were visual. The results of this quantitative analysis were consistent with those of the qualitative analysis provided in Figure 2 in showing differences in the effects of Pavlovian contingencies depending on whether the discriminative stimuli were auditory or visual. The differences in the intercept values across components were concordant with the differences in response rates (velocity) during baseline conditions. For most subjects the r^2 values were larger than .50, although there were a few instances of r^2 smaller than .50 that were probably attributable to the nonmonotonic effect of extinction for these functions.

DISCUSSION

These results show that the absolute and relative rates of target responding during conditions of reinforcement (Baselines 1, 2, and 3) were determined by the operant contingencies arranged within the multiple concurrent schedule. Furthermore, the rate of target responding varied inversely with the response-contingent reinforcement derived from a concurrent source. These findings were about the same regardless of whether the discriminative stimuli were auditory or visual and are consistent with the results of previous research on the behavioral effects of response-contingent alternative reinforcement (e.g., Catania, 1963). Conversely, the effect of alternative reinforcement upon resistance to change during extinction did depend on the modality of the discriminative stimuli. That is, resistance to extinction did not differ across the components with (Component 1) or with-

Fig. 2. The three columns of graphs correspond to the three extinction tests with their respective correlated component stimuli for all subjects. The y axis is arranged logarithmically. Each graph shows the mean rate of target responding for each component across the last 5 days of the preceding baseline (BL) and the rate of the target response for each component across successive 19.5-min blocks of the extinction session.

Table 6

The individual slopes, intercepts, and coefficients of determination (r^2) across the three components during Extinction 1, 2, and 3 (all subjects).

Rat	Component 1			Component 2			Component 3		
	Slope	Intercept	r^2	Slope	Intercept	r^2	Slope	Intercept	r^2
Extinction 1 (auditory stimuli)									
MV-24	-0.26	1.47	.66	-0.07	1.06	.77	-0.09	1.36	.74
MV-25	-0.40	1.79	.84	-0.29	1.62	.86	-0.61	2.50	.88
MV-26	-0.37	1.84	.56	-0.41	2.13	.88	-0.35	1.95	.72
MV-27	-0.54	1.38	.78	-0.37	1.20	.58	-0.65	1.61	.88
MV-28	-0.26	1.70	.76	-0.29	1.65	.98	-0.31	2.04	.78
MV-29	-0.13	1.17	.76	-0.28	1.56	.87	-0.30	1.84	.78
MV-30	-0.28	1.82	.76	-0.17	1.59	.90	-0.22	1.95	.50
MV-31	-0.27	1.51	.78	-0.28	1.46	1.00	-0.25	1.75	.95
Extinction 2 (visual stimuli)									
MV-24	-0.22	1.14	.84	-0.44	1.59	.85	-0.21	1.14	.69
MV-25	-0.30	1.63	.84	-0.74	2.06	.92	-0.38	2.11	.73
MV-26	-0.23	1.52	.73	-0.51	2.07	.76	-0.29	1.82	.78
MV-27	-0.01	0.67	.10	-0.19	0.63	.27	-0.12	0.88	.46
MV-28	-0.20	1.31	.42	-0.72	2.48	.86	-0.38	1.99	.84
MV-29	-0.39	1.48	.95	-0.55	1.52	.96	-0.35	1.53	.95
MV-30	-0.40	1.79	.94	-0.68	2.19	.89	-0.40	1.94	.95
MV-31	-0.17	1.41	.84	-0.35	1.47	.98	-0.26	1.79	.88
Extinction 3 (auditory stimuli)									
MV-24	-0.77	1.84	.70	-0.57	1.72	.76	-0.10	1.15	.89
MV-25	-0.51	1.81	.54	-0.31	1.63	.66	-0.68	2.52	.66
MV-26	-0.58	1.83	.73	-0.53	2.25	.87	-0.66	2.40	.67
MV-27	-0.40	0.80	.97	-0.53	1.51	.64	-0.89	1.89	1.00
MV-28	-0.39	0.90	.36	-0.34	1.48	.32	-0.50	1.58	.70
MV-29	-0.47	1.67	.84	-0.22	1.12	.75	-0.42	1.70	.54
MV-30	-0.50	1.85	.93	-0.18	1.29	.65	-0.32	1.77	.98
MV-31	-0.53	1.70	.89	-0.38	1.59	.92	-0.30	1.88	.88

out (Component 2) response-contingent alternative reinforcement when using auditory discriminative stimuli. In contrast, when the discriminative stimuli were visual, the resistance to extinction of the target response was greater in the component with alternative reinforcement than in the component that had not provided alternative reinforcement.

Thus, whether or not differences in the stimulus-reinforcer contingencies during baseline influenced resistance to change during extinction depended on whether the component-correlated stimuli were auditory or visual. The stimuli correlated with Components 1 and 3 signaled the same relatively high total rate of reinforcers (120 per hour), whereas the stimulus correlated with Component 2 signaled a lower rate of reinforcers (24 per hour). Thus, if resistance to change depended on the stimulus-reinforcer (Pavlovian) contingency, the target response should have been more resistant (equally so)

in Components 1 and 3 than in Component 2. Such differences occurred when the discriminative stimuli were visual but not when they were auditory. If, however, the differences in resistance to change were determined by response-reinforcer contingencies, then the resistance to change of the target response should have been less in Components 1 and 2 than in Component 3. No such effects were observed in any of the extinction tests.

It is unclear why the stimulus-reinforcer contingencies affected resistance to change only when the component-correlated stimuli were visual. Stimulus salience, however, may have played a role. The high-frequency tone in the present experiment may have been relatively more salient than the low-frequency tone, whereas the three visual stimuli may have been relatively equal in their salience. If so, then the effect of the Pavlovian contingencies in enhancing operant responding

during extinction may have been greater for the high-frequency tone than for the low-frequency tone. Assuming no differences in stimulus salience with visual stimuli, the effect of the Pavlovian contingencies is based solely on the reinforcement rates correlated with each visual discriminative stimulus. This account is consistent with our finding that differences in the sensory modality effect were mostly attributable to the lesser resistance to change during Component 2 of Extinction 2 compared to Component 2 of Extinction 1 and 3.

How might differences in Pavlovian contingencies contribute to differences in the resistance to change of operant behavior? Nevin et al. (1990) pointed out that arranging Pavlovian contingencies may have "nonspecific effects that arouse or modulate operant behavior (e.g., the 'central motive state' of Bindra, 1972, and Rescorla & Solomon, 1967...)" (p. 374). They further suggested that the strength of this modulatory effect should be a positive function of the reinforcement rate correlated with each component of the multiple concurrent schedule and so should the resistance to change of operant behavior across these components. Such an account is consistent both with their data and with the present experimental findings. The only difference in the present interpretation is the inclusion of stimulus salience to account for the difference in effects due to sensory modality.

One way of interpreting such "motivational" effects follows Michael's (1982, 1993) suggestion that the altering of operant behavior by a Pavlovian stimulus may be viewed as an establishing operation that changes the status of a reinforcer and evokes behavior related to the reinforcer. Moreover, the reinforcement-altering and response-evocative effects of such establishing operations may be positively related to the magnitude of the Pavlovian contingency. If so, differences in the strength of the establishing stimuli (auditory or visual) may extend across conditions of extinction to produce differences in resistance to change. The effectiveness of the establishing stimuli in evoking operant behavior during extinction may depend on the salience of the stimulus correlated with reinforcement.

An alternative interpretation of the sensory modality effect is based on stimulus location

and approach behavior to the conditional stimulus (i.e., sign tracking; Jenkins, Barrera, Ireland, & Woodside, 1978). The three auditory stimuli were in separate locations, whereas the three visual stimuli shared the same location in the operant chamber. This difference in stimulus location may have engendered differences in sign tracking that competed with lever pressing and could account for the differences in resistance to change between auditory and visual stimuli. This interpretation appears to be implausible because the high-frequency tone associated with Component 2 of Extinction 1 and 3 was the most remote stimulus in relation to the levers. This should have produced relatively *less* resistance to change with the high-frequency tone than did the 1 f/s visual stimulus (Component 2 of Extinction 2). Such differences were not observed.

Finally, the present experimental findings illustrate both the generality and the limits of the behavioral momentum effect. Cohen (1986) and Cohen et al. (1993) have shown species generality by successfully replicating the momentum effect with rats. The present research supplements their work by showing that differences in resistance to change (behavioral mass) in rats are determined by Pavlovian contingencies. These investigators also identified certain boundaries to the momentum effect, such as a failure to produce it using drugs as response disrupters or when using simple rather than multiple schedules. The limitation identified in the present experiment is that the influence of Pavlovian contingencies upon resistance to change depends upon stimulus properties, perhaps related to stimulus salience or modality. All stimuli are not equipotential in producing this effect.

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Received December 30, 1994
Final acceptance November 13, 1995