POSITIVE CONTRAST, NEGATIVE INDUCTION, AND INHIBITORY STIMULUS CONTROL IN THE RAT¹

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In Experiment I, 24 rats were trained on a multiple variable-interval variable-interval schedule with a doorlight and white noise serving as component cues. Two groups were then shifted to a multiple extinction variable-interval schedule, and a third group was maintained on the multiple variable-interval variable-interval schedule. The multiple extinction variable-interval condition produced positive contrast when either the light or noise signalled extinction, and both of these cues acquired inhibitory stimulus control as measured by a combined cue test. In Experiment II, the multiple variable-interval variable-interval condition was shifted to multiple extinction variable-interval for one group, to multiple variable-time variable-interval for a second group, and was unchanged for the third group. The two experimental conditions produced identical patterns of response-rate reduction in the altered component, but the multiple extinction variable-interval condition produced positive contrast, whereas the multiple variable-time variable-interval condition did not. Subsequent combined cue and resistance to reinforcement tests revealed that the cue signalling extinction acquired stronger inhibitory stimulus control than the cue signalling variable time.

Key words: positive contrast, negative induction, inhibitory stimulus control, multiple schedules, rats

Positive behavioral contrast occurs when the alteration in one component of a two-component multiple schedule (*i.e.*, *mult* S1 S2) results in a decrease in the response rate in the altered (S1) component, and an increase in the response rate in the unaltered (S2) component. Negative induction occurs when the alteration in S1 results in a decrease in the response rate in both S1 and S2. Positive contrast has been obtained reliably by shifting a multiple variable-interval variable-interval (*mult* VI VI) schedule to multiple extinction vari-

able-interval (*mult* EXT VI) (*e.g.*, Reynolds, 1961), and negative induction, by shifting the *mult* VI VI condition to multiple variable-time variable-interval (*mult* VT VI) (*e.g.*, Halliday and Boakes, 1971). Most of the research on multiple schedule interactions has been concerned with determining the necessary and sufficient conditions for positive contrast. An important strategy used in several studies has been to compare the conditions that produce positive contrast with those that produce negative induction (*e.g.*, Halliday and Boakes, 1971; 1972; Wilkie, 1972). Since these two interactions are characterized by similar changes in the response rate in S1 but opposite changes in S2, it is assumed that a factor(s) common to both cannot cause either.

For example, consider Halliday and Boakes's (1972) proposal that positive contrast is a function of the inhibitory stimulus control acquired by the cue signalling the S1 component of the multiple schedule. It is well documented that the gradient of generalization around the extinction cue of the *mult* EXT VI condition is U-shaped (*cf.* Terrace, 1966). But the U-shaped gradient has also been obtained around the variable-time cue of the *mult* VT VI condition (Weisman and Ramsden, 1973).

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Thus, inhibitory stimulus control is not a sufficient condition for positive contrast.

However, it is possible that the U-shaped gradient reflects both operant and Pavlovian inhibition. The former is based on the absence of a contingency between the response and reinforcer, and the latter on the absence of a contingency between the stimulus and reinforcer. The shift from variable interval to either extinction or variable time represents a shift from the presence to the absence of a response/reinforcer contingency. But the extinction cue of the *mult* EXT VI condition is also associated with the absence of the reinforcer, whereas the variable-time cue of the *mult* VT VI condition is not. Consequently, both cues contain an operant source of inhibition, but only the extinction cue contains a potential Pavlovian source. If both sources are capable of producing inhibitory stimulus control, it follows that the inhibitory stimulus control of the extinction cue should be stronger than the inhibitory stimulus control of the variable time cue. The present study was designed to make this comparison.

EXPERIMENT I

The U-shaped gradient has served as the operational definition of inhibitory stimulus control for most investigators. However, this measure has been used to determine only the presence or absence of the effect. A comparison between two inhibitory stimuli poses at least two problems. First, the U-shaped gradient often reflects extremely low response rates, and thus reduces the area in which two different functions can emerge. Second, even if two different functions do emerge, what is the criterion for determining which function reflects the greater magnitude of inhibitory stimulus control? These issues have been discussed in detail by Hearst, Besley, and Farthing (1970). They asserted that inhibitory stimulus control can be measured only against a baseline of excitatory stimulus control. For example, the generalization gradient procedure compares a conditioned cue to novel cues lying on the same physical continuum. Consequently, a U-shaped gradient could emerge if the conditioned cue is simply less excitatory than the novel cues. The combined cue test on the other hand compares the conditioned cue to a known excitatory cue, and inhibitory stimulus con-

trol is inferred if the compound of these two cues controls a lower response rate than the known excitatory cue. It should be noted that if the conditioned cue is simply less excitatory than the known excitatory cue, the compound would be expected to control a response rate greater than or equal to either of these cues. More importantly, the combined cue test affords the opportunity for making quantitative comparisons, since the stronger of two inhibitory stimuli should produce greater response suppression to the compound relative to the known excitatory cue. Experiment I used the combined cue test to demonstrate and compare the inhibitory stimulus control of two different cues signalling the extinction component of the *mult* EXT VI condition.

METHOD

Subjects

Twenty-four experimentally naive female hooded rats (90 to 100 days of age) from the colony at the Experimental Psychology Laboratory, Syracuse University, were maintained at approximately 80 to 85% of free-feeding weights.

Apparatus

Four Grason-Stadler operant chambers (29.5 by 24.0 by 19.5 cm) were mounted in sound-attenuating enclosures containing exhaust fans that ventilated the chambers and masked extraneous sounds. The chambers contained a single response lever located in the middle of the front panel, 9.5 cm above the grid floor, protruding 1.5 cm into the chamber. Operation of the lever required approximately 0.16 to 0.18 N of force. Standard 45-mg Noyes pellets were delivered into the magazine located 3.0 cm directly below the lever. The chambers contained three additional exteroceptive stimulus sources. A 10-W bayonet lamp (GE #10C7/DC) was located behind a red plastic dome, 1.0 cm above and 7.0 cm to the left of the lever; a second 10-W lamp was located on the outside of the Plexiglas chamber door, 8.0 cm above and 10.0 cm to the right of the lever, and white noise (75 dB-SPL) was delivered through a speaker located on the left side of the front panel, below the level of the grid floor. The red domelight served as a houselight, and the doorlight and white noise served as component cues in the multiple schedule.

Procedure

Subjects received three sessions of lever-press training on a continuous reinforcement schedule (60 pellets per session), followed by 20 sessions of training in Phase 1, 12 sessions in Phase 2, and a single session of the combined cue test.

Phase 1. After lever-press training, subjects were placed directly on a *mult* VI 30-sec VI 30-sec schedule, which consisted of 10, 3-min presentations of S1 and 10, 3-min presentations of S2 occurring in strict alternation beginning with S1. The houselight was on during S1 and S2, and was off during 4-sec blackout intervals that separated the components. In Phase 1, the doorlight signalled the S1 component, and the white noise signalled the S2 component.

Phase 2. Subjects were matched according to their response rates in Sessions 16 to 20 of Phase 1, and placed into one of three groups ($n =$ eight per group) in Phase 2. The Light-Extinction group received a *mult* light(EXT) noise(VI) treatment, and the Noise-Extinction group received a *mult* noise(EXT) light(VI) treatment. The Control group remained on the *mult* VI VI condition of Phase 1 for the entire 12 sessions of Phase 2. Since the Noise-Extinction treatment reversed the order of presentation of the light and noise cues, four of the Control subjects received *mult* light(VI) noise(VI), and four received *mult* noise(VI) light(VI).

Combined cue test. The combined cue test was administered after the last session of Phase 2. The test procedure consisted of four cycles (or blocks) of a two-component multiple schedule. The S1 component of this schedule was 9 min in duration, and consisted of a VI 30-sec schedule administered in the presence of the variable-interval cue from the S2 component of Phase 2 (i.e., noise for the Light-Extinction group, light for the Noise-Extinction group, and light for four subjects and noise for the other four subjects in the Control group). The S2 component was 6 min and 20 sec in duration, and was subdivided into six 1-min intervals separated by the 4-sec blackout interval. An extinction schedule was in force throughout S2 as 1-min presentations of the light, noise, and light/noise compound cues were administered. The order of presentation of these cues was counterbalanced so that two presentations of each of the three cues were

administered in each of the four S2 components. As in Phases 1 and 2, the houselight was on during S1 and S2, and off during 4-sec blackout intervals that served to separate the S1 and S2 components.

RESULTS

Phases 1 and 2. The last five sessions of Phase 1 and the 12 sessions of Phase 2 were treated as one block of five and four blocks of three sessions, respectively. Response rates (responses per minute) for individual subjects were summed and averaged across blocks, and these averages are presented in the first 10 columns of Table 1.

Inspection of Table 1 reveals that the subjects in the Light-Extinction and Noise-Extinction groups showed positive contrast in Phase 2 relative to the *mult* VI VI response rates of the subjects in the Control group. More specifically, all eight subjects in the Light-Extinction group showed a decrease in the response rate in extinction and an increase in variable interval, as did seven of the eight subjects in the Noise-Extinction group. In comparison, three of eight subjects in the Control group (Rats 11, 14, and 16) did not show an increase in the *mult* VI VI response rate, and four subjects (Rats 9, 10, 12, and 13) showed small increases that were confined primarily to the last block. Only one subject in the Control group (Rat 15) showed an increase in *mult* VI VI response rate comparable to the increase in variable-interval response rate shown by the majority of subjects in the two experimental groups.

These observations were confirmed in group comparisons. Figure 1 depicts the group mean response rates of the Noise-Extinction (bottom panels) and Light-Extinction (top panels) groups for the last five sessions of Phase 1 (P1) and the 12 sessions of Phase 2 (P2). The dashed functions depict the unaltered components of the two experimental groups, and are represented in both phases. The dotted functions depict the altered components of these two groups, and are represented in Phase 2 only. The solid functions depict the Control group, and represent the light(VI) and noise(VI) components, bottom and top panels, respectively. Inspection of the Phase 1 panels reveals that response rates did not differ among the three groups over the last five sessions of Phase 1. A 2×4 (groups $\times$ blocks) Anova comparing the vari-

Table 1
Average Response Rates for Individual Subjects during the Phase 1 Block, the four Phase 2 Blocks, and the Combined Cue Test of Experiment I

	Baseline		Block-1		Block-2		Block-3		Block-4		Combined Cue Test	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	Light	Noise Compound
<i>Control:</i>												
Rat 9	21.4	18.8	23.9	20.7	21.4	21.8	20.3	19.8	26.7	29.1	25.4	23.1
Rat 10	10.7	9.9	12.7	12.2	12.4	12.9	14.1	14.9	17.6	16.4	31.4	23.0
Rat 11	35.4	47.9	36.1	41.6	29.7	34.9	32.0	36.3	28.8	37.6	25.8	36.1
Rat 12	26.0	24.7	26.1	20.0	27.8	23.4	29.6	24.6	31.7	27.9	30.1	27.4
Rat 13	27.1	22.1	27.6	22.3	28.2	24.5	24.0	20.7	35.2	28.3	36.4	29.1
Rat 14	18.2	17.5	17.4	17.6	18.6	19.7	17.2	17.7	18.3	17.3	18.0	24.9
Rat 15	34.3	33.6	43.8	39.2	45.8	49.3	53.5	49.3	66.5	64.4	57.7	54.6
Rat 16	14.1	15.2	15.8	17.5	15.4	15.5	16.4	16.0	16.0	16.8	19.1	25.0
<i>L-EXT:</i>												
Rat 1	27.4	29.4	25.2	43.0	15.2	50.2	9.8	47.9	8.2	63.2	4.8	68.1
Rat 2	15.6	11.6	14.9	29.1	5.3	24.2	1.8	18.5	2.8	29.3	0.8	5.8
Rat 3	18.6	16.0	13.4	23.1	5.0	26.2	7.0	32.8	4.2	33.1	1.1	7.5
Rat 4	33.0	33.0	29.7	40.9	16.4	39.7	10.0	47.0	11.3	48.5	2.9	33.8
Rat 21	26.0	25.4	22.1	34.0	13.4	35.2	7.2	29.2	8.3	33.6	8.1	27.1
Rat 22	13.5	13.1	15.5	17.8	7.6	19.2	5.3	20.1	5.1	16.7	6.4	15.6
Rat 23	23.2	23.3	17.9	32.8	12.9	36.5	10.5	35.2	8.2	35.5	5.0	27.8
Rat 24	23.1	23.9	20.9	29.6	15.9	34.2	7.5	36.1	10.5	41.7	3.5	29.9
<i>N-EXT:</i>												
Rat 5	35.1	34.9	28.8	48.7	19.4	44.5	20.0	45.0	13.5	63.3	39.9	12.5
Rat 6	16.5	18.6	17.9	39.5	11.3	48.4	5.5	46.8	6.9	46.4	53.1	10.1
Rat 7	22.0	18.6	14.3	26.4	11.0	33.2	5.5	28.5	4.2	30.2	16.5	1.8
Rat 8	29.3	31.8	25.2	33.9	18.0	38.1	8.9	34.1	10.4	36.9	25.2	3.5
Rat 17	6.6	10.9	6.7	11.0	2.8	8.3	1.3	6.4	1.7	10.9	6.1	1.8
Rat 18	38.2	31.7	30.0	50.5	18.4	53.0	18.7	53.8	12.6	58.1	40.9	2.3
Rat 19	21.7	20.3	19.9	37.7	12.6	41.2	10.2	40.8	7.7	41.1	25.2	2.1
Rat 20	17.4	19.7	12.0	19.3	9.4	30.9	9.7	37.9	5.8	43.6	23.3	0.5

able-interval response rates of the Noise-Extinction and Control groups (*i.e.*, in the light(VI) component for both groups) in Phase 2 resulted in a significant groups effect ($F_{1,56} = 8.9$; $p < 0.01$), as did a 2×4 Anova comparing the variable-interval response rates of the Light-Extinction and Control groups (*i.e.*, in the noise(VI) component for both groups) ($F_{1,56} = 7.9$; $p < 0.01$). In both cases, response rates were significantly higher in the experimental groups. Additional 2×4 Anovas comparing the response rates in the extinction and variable-interval components of the two experimental groups did not result in significant groups effects ($F_s < 1.0$).

Combined cue test. Response rates were computed at each block of the combined cue test. These rates were summed and averaged across blocks for individual subjects, and these averages are presented in the last three columns of Table 1.

Table 1 reveals that all eight subjects in the Light-Extinction group showed response suppression to the compound relative to the noise(VI) cue, and greater suppression to the light(EXT) cue than the compound. Similarly, seven of eight subjects in the Noise-Extinction group showed response suppression to the compound relative to the light(VI) cue; and all eight showed greater suppression to the noise(EXT) cue than the compound. In comparison, six of eight subjects in the Control group (Rats 9, 10, 11, 12, 13, and 15) showed slightly higher response rates to the compound than either the light or noise cues.

These observations were confirmed in within-group comparisons. A 3×4 (cues $\times$ blocks) Anova comparing the response rates of the Control group to the three cues at the four blocks of the combined cue test did not result in significant effects ($F < 1.0$). In comparison, the response rates were lower to the compound than the noise(VI) cue ($F_{1,56} = 22.7$; $p < 0.01$), and lower to the light(EXT) cue than the compound ($F_{1,56} = 11.8$; $p < 0.01$) in the Light-Extinction group. Similarly, the response rates were lower to the compound than the light(VI) cue ($F_{1,56} = 13.6$; $p < 0.01$), and lower to the noise(EXT) cue than the compound ($F_{1,56} = 4.6$; $p < 0.05$) in the Noise-Extinction group.

Additional comparisons were made between the Light-Extinction and Noise-Extinction groups. These comparisons were made by converting the response rates to suppression ratios.

Fig. 1. Group mean response rates in Experiment I for the last five sessions of Phase 1 (P1) and the 12 sessions of Phase 2 (P2). The bottom panels compare the light(VI) response rates of the Noise-Extinction and Control groups, and the top panels the noise(VI) response rates of the Light-Extinction and Control groups (*i.e.*, dashed versus solid functions, respectively in P1 and P2 in both panels). The dotted functions in P2 represent the extinction response rates for both experimental groups.

The formula $B/(A + B)$ was used, where A represents the response rate to the variable-interval cue, and B the response rate to the extinction cue and the compound. Thus, ratios of less than 0.50 indicate response suppression to the extinction and/or compound cue relative to the variable-interval cue. The group mean suppression ratios are plotted in the left (Noise-Extinction) and right (Light-Extinction) panels of Figure 2 for the compound (solid functions) and extinction (dotted functions) cues.

Figure 2 shows that the suppression ratios for the two groups were on the whole comparable, although differences were evident at specific blocks. Statistically, a 2×4 (cues $\times$ blocks) Anova comparing the suppression ratios of the two groups to the compound resulted in a significant interaction effect ($F_{3,56} = 4.9$; $p < 0.05$), as did a 2×4 Anova comparing the suppression ratios of the two groups to the extinction cue ($F_{3,56} = 3.0$; $p < 0.05$). Analysis of the simple main effects re-

vealed that the Light-Extinction group showed greater response suppression to the compound at Block-4 ($F_{1,56} = 12.6$; $p < 0.01$), and greater suppression to the extinction cue at Block-4 ($F_{1,56} = 5.8$; $p < 0.05$); and the Noise-Extinction group showed greater suppression to the extinction cue at Block-1 ($F_{1,56} = 5.9$; $p < 0.05$).

DISCUSSION

The procedures used in Phases 1 and 2 of Experiment I replicate part of the procedures used by Mackintosh, Little, and Lord (1972) and Gutman, Sutterer, and Brush (1975). In the Gutman *et al.* (1975) study, positive and negative contrast were obtained in Phases 2 (*mult* EXT VI) and 3 (*mult* VI VI), respectively, and were reproduced in Phases 4 (*mult* EXT VI) and 5 (*mult* VI VI) as well. Thus, it is not surprising that positive contrast was obtained in the rat in the present study.

The results of the combined cue test confirm the earlier findings of Cornell and Strubb (1965) in the rat, and Davis (1971) in the pigeon. The compound of the variable-interval and extinction cues controlled a lower response rate than the variable-interval cue in isolation, indicating that the extinction cue acquired inhibitory stimulus control. This finding cannot be attributed to the novelty of the compound, since the Control group failed to show response suppression to this cue. Neither can it be attributed to inattention to the variable-interval element of the compound, since equal response rates to the extinction cue and the compound would be the expected outcome, given this factor.

EXPERIMENT II

Experiment II was designed to compare the inhibitory stimulus control of the cues signaling the extinction and variable-time components of the *mult* EXT VI and *mult* VT VI conditions. The combined cue test was used to compare the response suppression to the compounds of the variable-interval + extinction and variable-interval + variable-time cues. Subsequently, a resistance to reinforcement test (*cf.* Hearst *et al.*, 1970) was used to ensure that the effects obtained in the combined cue test were a function of associational factors. That is, in Experiment I, the response suppression obtained to the compound of the variable-interval + extinction cue was attrib-

Fig. 2. Group mean suppression ratios in Experiment I computed at each of the four blocks of the combined cue test for the Light-Extinction (left panel) and Noise-Extinction (right panel) groups. The solid functions represent response suppression to the compound, and the dotted functions response suppression to the extinction cue, for both experimental groups.

uted to the association between the extinction cue and the extinction schedule. In the resistance to reinforcement test procedure, the cues were again combined as in the combined cue test, but in the context of the *mult* VI VI baseline condition. The purpose of this procedure was to change the stimulus-schedule associations of the extinction and variable-time cues, and to determine whether these changes would weaken the response suppression to the compounds of the variable-interval + extinction and variable-interval + variable-time cues. Moreover, it was assumed that the stronger of the two inhibitory stimuli should support greater response suppression to the compound in the combined cue test, and that the response suppression supported by the stronger inhibitory stimulus should take longer to weaken (*i.e.*, be more resistant to reinforcement) in the resistance to reinforcement test.

METHOD

Subjects

Twenty-four experimentally naive female hooded rats (90 to 100 days of age) from the colony at the Experimental Psychology Laboratory, Syracuse University, were reduced to and maintained at approximately 80 to 85% of free-feeding weights.

Apparatus

The apparatus was the same as that of Experiment I.

Procedure

The subjects in Experiment II were treated identically to those in Experiment I, up to and including the twentieth session of *mult* light(VI) noise(VI) baseline training. They were subsequently matched according to their response rates in Sessions 16 to 20 of Phase 1, and placed into one of three groups in Phase 2. The Extinction group received *mult* light(EXT) noise(VI 30-sec); the Variable-Time group received *mult* light(VT 30-sec) noise(VI 30-sec); and the Control group continued on the baseline condition. After 12 sessions of training in Phase 2 and a single session of the combined cue test, subjects received two additional sessions of the Phase 2 treatment, followed by three sessions of the resistance to reinforcement test. The procedure used in the combined cue test was identical to that used in Experiment I. That is, four 9-min

components of VI 30-sec in the presence of the variable-interval cue from Phase 2 (*i.e.*, noise for all three groups) alternated with four 6-min components of extinction, during which the light, noise, and compound cues were tested. The resistance to reinforcement test procedure consisted of five cycles (or blocks) of a three-component multiple schedule. The first two components of this schedule constituted a *mult* light(VI) noise(VI) condition with component durations of 3 min (*i.e.*, the baseline condition). The third component consisted of 6 min of extinction, during which the 1-min presentations of the light, noise and compound cues occurred (*i.e.*, as in the combined cue test).

RESULTS

Phases 1 and 2. The last five sessions of Phase 1 and the 12 sessions of Phase 2 were again treated as one block of five and four blocks of three sessions, respectively. Response rates for the individual subjects were summed and averaged across blocks, and are presented in the first 10 columns of Table 2.

Inspection of Table 2 reveals three basic findings. First, all eight subjects in the Extinction group showed a decrease in response rate in extinction and an increase in variable interval in Phase 2. In comparison, only one of eight subjects in the Control group (Rat 3) showed an increase in response rate in *mult* VI VI. Second, five of eight subjects in the Variable-Time group (Rats 9, 10, 13, 14, and 15) showed negative induction in Phase 2 (*i.e.*, a decreased response rate in both the variable-time and variable-interval components). However, comparable decreases of the *mult* VI VI response rate were shown by at least four subjects in the Control group (Rats 1, 2, 4, and 17). Third, there was no apparent difference in the speed or magnitude of response-rate reduction between subjects in the two experimental groups in the extinction and variable-time components of the *mult* EXT VI and *mult* VT VI conditions of Phase 2.

These observations were confirmed in group comparisons. Figure 3 depicts the group mean response rates of the Extinction (bottom panels) and Variable-Time (top panels) groups for the last five sessions of Phase 1 (P1) and the 12 sessions of Phase 2 (P2). The dashed functions depict the unaltered components of the two experimental groups, and are repre-

Table 2
Average Response Rates for Individual Subjects during the Phase 1 Block, the four Phase 2 Blocks, and the Combined Cue Test of Experiment II

	Baseline		Block-1		Block-2		Block-3		Block-4		Combined Cue Test	
	SI	S2	SI	S2	SI	S2	SI	S2	SI	S2	Light	Noise Compound
<i>Control:</i>												
Rat 1	25.6	30.0	21.0	19.5	29.2	33.1	28.6	25.2	32.6	27.4	34.4	28.1
Rat 2	14.3	18.8	10.3	13.3	11.2	11.6	11.1	11.7	8.9	10.4	7.1	12.6
Rat 3	30.9	30.4	30.5	33.2	37.8	41.9	41.9	46.0	34.8	41.8	19.1	26.9
Rat 4	26.9	20.0	19.0	13.1	21.1	14.0	25.4	18.3	25.1	17.6	25.5	21.8
Rat 17	55.2	52.7	52.5	48.7	47.5	43.9	43.6	40.8	46.6	43.5	30.3	35.1
Rat 18	39.8	37.6	38.6	34.0	39.4	36.6	38.2	37.2	43.2	42.0	32.0	33.1
Rat 19	35.3	33.4	39.9	37.0	34.0	33.1	37.2	34.5	34.9	34.9	29.0	32.1
Rat 20	28.3	30.0	26.7	24.7	21.6	26.2	23.4	25.6	22.3	30.4	17.8	32.3
<i>EXT:</i>												
Rat 5	23.6	20.6	16.6	39.0	8.5	38.4	5.3	34.5	3.8	38.4	1.6	25.5
Rat 6	27.6	28.4	20.9	33.3	12.6	34.3	10.4	34.8	10.2	36.4	8.8	33.5
Rat 7	25.8	25.9	24.0	47.3	10.0	45.0	6.3	46.9	4.3	44.8	0.1	30.3
Rat 8	25.4	18.2	23.8	37.3	16.4	45.4	11.4	41.1	8.9	43.1	1.4	21.9
Rat 21	21.7	18.8	20.6	32.2	12.9	35.6	9.1	32.5	9.7	39.5	5.6	14.3
Rat 22	51.0	52.8	36.9	66.9	14.6	58.3	12.1	59.3	12.2	60.5	10.6	50.1
Rat 23	32.1	34.5	31.2	54.2	15.1	49.0	13.7	59.1	11.8	58.3	7.0	22.2
Rat 24	28.7	32.6	30.2	59.5	10.7	51.7	7.8	45.8	10.6	56.1	7.8	44.6
<i>VT:</i>												
Rat 9	30.9	28.2	18.8	22.3	13.4	25.6	18.9	28.2	8.7	26.9	19.3	39.9
Rat 10	25.3	26.6	15.3	21.3	9.0	18.9	8.6	18.7	9.6	23.1	15.9	24.0
Rat 11	44.0	41.3	39.4	42.1	23.1	34.1	28.9	44.4	29.8	45.5	33.5	52.1
Rat 12	30.3	31.6	15.8	31.5	7.7	38.9	4.6	38.2	9.7	40.6	14.2	41.3
Rat 13	16.5	18.6	9.7	18.1	8.6	18.6	3.3	16.3	1.3	16.0	6.0	18.8
Rat 14	26.3	23.3	15.4	20.2	6.0	21.6	2.9	19.4	1.2	17.3	9.8	21.1
Rat 15	51.3	46.0	20.3	29.8	18.4	27.2	10.1	27.8	3.2	28.3	21.3	37.8
Rat 16	43.9	41.6	31.6	34.3	31.4	38.3	22.5	36.7	27.4	43.1	32.0	46.4

sented in both phases. The dotted functions depict the altered components of these two groups, and are represented in Phase 2 only. The solid functions depict the Control group, and represent the noise (VI) component of the *mult* VI VI condition in both the bottom and top panels. The Phase 1 panels reveal that response rates did not differ among the three groups over the last five sessions of Phase 1. A 2×4 (groups $\times$ blocks) Anova comparing the variable-interval response rates of the Extinction and Control groups in Phase 2 revealed that the response rate was significantly higher for the Extinction group ($F_{1,56} = 33.7$; $p < 0.01$). Additional 2×4 Anovas comparing the variable-interval response rates of the Variable-Time and Control groups, as well as the extinction and variable-time response rates of the Extinction and Variable-Time groups, did not result in significant groups effects ($F_s < 1.0$).

Combined cue and resistance to reinforcement tests. Response rates were computed to the three cues at each of the four blocks of the combined cue test, and at each of the five blocks of the three resistance to reinforcement tests. The response rates were summed and averaged across the blocks of the combined cue test, and these averages are presented in the last three columns of Table 2.

Control group. Table 2 shows that subjects in the Control group did not respond differentially to the light, noise, and compound cues at the combined cue test. This was confirmed via a 3×4 (cues $\times$ tests) Anova, which also revealed no difference in the response rate to the three cues at the three resistance to reinforcement tests ($F < 1.0$).

Extinction group. Table 2 reveals that all eight subjects in the Extinction group showed response suppression to the compound relative to the noise(VI) cue, and that seven of them showed greater suppression to the light(EXT) cue than the compound, at the combined cue test.

The relationship between response suppression to the compound in the combined cue and resistance to reinforcement tests can be seen in Figure 4. The left panels depict the individual subjects in the Extinction (EXT) group, and the right panels those in the Variable-Time (VT) group. The individual data points in each panel represent suppression ratios computed from the response rates after

Fig. 3. Group mean response rates in Experiment II for the last five sessions of Phase 1 (P1) and the 12 sessions of Phase 2 (P2). The bottom panels compare the noise(VI) response rates of the Extinction and Control groups, and the top panels the noise(VI) response rates of the Variable-Time and Control groups (*i.e.*, dashed versus solid functions, respectively in P1 and P2 in both panels). The dotted functions in P2 represent the extinction and variable-time response rates for the respective experimental groups.

they were averaged across the blocks of the tests. The left panels of Figure 4 reveal that all eight subjects in the Extinction group showed a decrease in response suppression (*i.e.*, an increase in suppression ratio values toward 0.5) to the compound (solid functions) in going from the combined cue test (*i.e.*, data points before the dashed vertical lines) to the resistance to reinforcement tests (*i.e.*, data points after the dashed vertical line).

These observations were confirmed in group comparisons. For statistical purposes, response rates were summed and averaged across the blocks of the combined cue test and three resistance to reinforcement tests. A 2×4 (cues $\times$ tests) Anova comparing the response rates to the noise(VI) cue and the compound resulted in a significant cues effect ($F_{1,45} = 36.0$; $p < 0.01$), as did a 2×4 Anova comparing the response rates to the light(EXT) cue and the compound ($F_{1,56} = 12.1$; $p < 0.01$). Subsequent comparisons were made via the *t*-test, and revealed that the response rate was lower to the compound than the noise (VI) cue ($t_{56} = 3.4$; $p < 0.01$), and lower to the light(EXT) cue than the compound ($t_{56} = 3.1$; $p < 0.01$) at the combined cue test, thus replicating the finding obtained in Experiment I. Additional comparisons revealed that the response rate remained lower to the compound than the noise(VI) cue at the first ($t_{56} = 2.6$; $p < 0.01$) and second ($t_{56} = 2.1$; $p < 0.05$) but not at the third resistance to reinforcement test. In other words, the inhibitory control of the light(EXT) cue was eliminated during the latter test.

Variable-time group. Table 2 reveals that seven of eight subjects in the Variable-Time group showed response suppression to the compound relative to the noise(VI) cue, and that five of these subjects (Rats 9, 12, 13, 14, and 15) showed greater suppression to the light(VT) cue than the compound, at the combined cue test.

The right panels of Figure 4 reveal that the response suppression to the compound decreased during the resistance to reinforcement tests for five subjects (Rats 9, 10, 11, 13, and 16) that showed suppression to the compound at the combined cue test. Thus, although there was less uniformity in this group, compared to the Extinction group, it would appear that the light(VT) cue was inhibitory during the combined cue test, and that the inhibitory con-

trol of this cue diminished during the resistance to reinforcement tests.

These observations were confirmed in group comparisons. A 2×4 (cues $\times$ tests) Anova comparing the response rates to the noise(VI) cue and the compound resulted in a significant cues effect ($F_{1,56} = 7.0$; $p < 0.01$), and the response rate was lower to the compound than the noise(VI) cue at the combined cue test ($t_{56} = 2.1$; $p < 0.05$). A 2×4 Anova comparing the response rates to the light(VT) cue and the compound did not result in a significant cues effect, but a 2×4 Anova comparing the suppression ratios to these cues did ($F_{1,56} = 8.6$; $p < 0.01$). The comparison at the combined cue test revealed that the response suppression was greater to the light(VT) cue than the compound ($t_{56} = 2.1$; $p < 0.05$). Additional comparisons revealed that the response rates to the noise(VI) cue and the compound did not differ at any of the resistance to reinforcement tests. Thus, the light(VT) cue did acquire inhibitory stimulus control, and only one resistance to reinforcement test was needed to eliminate this control.

Extinction group versus variable-time group. On the basis of the within-group comparisons made above, the Extinction group showed greater resistance to reinforcement than the Variable-Time group. This follows because three resistance to reinforcement tests were needed to eliminate the response suppression to the compound for the Extinction group, whereas only one such test was needed for the Variable-Time group.

In addition, there were between-group differences with respect to response suppression to both the compound and the light cue at both the combined cue and resistance to reinforcement tests. These differences were of course greatest at the combined cue test, since suppression to both cues was weakened during the resistance to reinforcement tests. For example, Figure 4 reveals very little overlap between the response suppression of subjects in the Extinction and Variable-Time groups at the combined cue test (*i.e.*, the data points before the dashed vertical line). Notice that the smallest amount of suppression to the compound (solid functions) in the Extinction group (*i.e.*, Rats 21 and 22) was about equal to largest amount of suppression to this cue in the Variable-Time group (*i.e.*, Rat 13), and that the smallest amount of suppression to the

Fig. 4. Suppression ratios representing the stimulus control tests in Experiment II for the individual subjects in the Extinction (left panels) and Variable-Time (right panels) groups. Each panel contains four data points, and each data point represents an average taken across the blocks of one of the tests. The first point in each panel (*i.e.*, before the dashed vertical line) represents the combined cue test, and the remaining points (*i.e.*, after the dashed vertical line) three resistance to reinforcement tests. The solid functions represent response suppression to the compound, and the dotted functions response suppression to the variable-time and extinction cues for the respective groups.

Fig. 5. Group mean suppression ratios representing the stimulus-control tests in Experiment II for the Extinction (bottom panels) and Variable-Time (top panels) groups. The data points before the dashed vertical line represent the four blocks of the combined cue test, and the data points after the dashed vertical line represent the five blocks of the three resistance to reinforcement tests. The solid functions represent response suppression to the compound, and the dotted functions response suppression to the variable-time and extinction cues for the respective groups.

light cue (dotted functions) in the Extinction group (*i.e.*, Rats 21 and 23) was about equal to the largest amount of suppression to this cue in the Variable-Time group (*i.e.*, Rats 12 and 13).

These relationships are also evident in Figure 5, which depicts the group mean suppression ratios at each block of the combined cue test (*i.e.*, the data points before the dashed vertical line) and at each block of the three resistance to reinforcement tests (*i.e.*, the data points after the dashed vertical line) for both the Extinction (bottom panels) and Variable-Time (top panels) groups. For statistical purposes, suppression ratios for individual subjects were summed and averaged across the blocks of each test, and 2×4 (groups $\times$ tests) Anovas were computed to compare the ratios of the two groups for both the compound and the light cue. As expected, the Anovas for both the compound and the light cue resulted in significant groups effects ($F_{1,56} = 22.9$ and 25.4 ; $p < 0.01$ and 0.01). The subsequent comparisons revealed that the Extinction group showed significantly greater suppression than the Variable-Time group to the compound at the combined cue test ($t_{56} = 3.6$; $p < 0.01$) and at the first two resistance to reinforcement tests ($t_{56} = 2.6$ and 2.1 ; $p < 0.01$ and 0.05); and to the light cue at the combined cue test ($t_{56} = 3.4$; $p < 0.01$) and at all three resistance to reinforcement tests ($t_{56} = 5.3$, 2.3 , and 2.1 ; $p < 0.01$, 0.01 , and 0.05).

The difference in response suppression to the light cue is of particular interest, since the extinction and variable-time schedules controlled equal response rates in the S1 component of Phase 2. The cause of this difference would appear to be related to the transition from the Phase 2 treatment to the combined cue test. Specifically, comparison of the response rates in columns 9 (*i.e.*, S1, Block 4 of Phase 2) and 11 (*i.e.*, the light component of the combined cue test) of Table 2 reveals that all eight subjects in the Extinction group showed a decrease, whereas all eight subjects in the Variable-Time group showed an increase in response rate to the light cue in the transition from the terminal block of Phase 2 to the combined cue test.

DISCUSSION

The failure to obtain a statistically reliable negative induction effect with the *mult* VI VI-

mult VT VI procedure is not surprising. Halliday and Boakes' (1971, 1972) and Weisman and Ramsden's (1973) data reveal that the effect is characterized by only a 15 to 20% reduction in response rate in the variable-interval component of Phase 2, and that it does not occur in all subjects. More importantly, the variable-time cue did acquire inhibitory stimulus control as measured by the combined cue test, thus confirming Weisman and Ramsden's earlier finding with the generalization gradient.

As expected, the *mult* VI VI-*mult* EXT VI procedure produced both positive contrast and inhibitory stimulus control. Furthermore, as predicted, the extinction cue of the *mult* EXT VI condition produced an inhibitory combined cue effect that was initially larger, and subsequently more resistant to reinforcement than the variable-time cue of the *mult* VT VI condition.

However, it was not expected that the extinction and variable-time schedules would control equal response rates in Phase 2. Intuitively, it would seem that the stronger of two inhibitory stimuli should control a lower response rate. However, it should be noted that the response-independent reinforcer of the variable-time schedule was not administered during the combined cue test. Since the removal of the response-independent reinforcer coincided with an increase of the response rate controlled by the light(VT) cue in the combined cue test (*i.e.*, relative to the terminal block of Phase 2), the reinforcer itself may have served as a discriminative stimulus for not responding in Phase 2. Thus, the response rate in the extinction and variable-time schedules of Phase 2 may have been equal because the variable-time schedule has two sources of operant inhibition (*i.e.*, the component cue and the reinforcer), which summated to equal the inhibitory control of the extinction schedule. Furthermore, the response rate to the light(EXT) and light(VT) cues in the combined cue test may have differed because of the removal of one of these sources (*i.e.*, the response-independent reinforcer).

GENERAL DISCUSSION

The findings obtained in Experiment II are suggestive of two accounts for the difference in the multiple schedule interaction normally ob-

tained with the *mult VI VI-mult EXT VI* and *mult VI VI-mult VT VI* procedures. First, assume that the reinforcer in the variable-time component of the *mult VT VI* condition does acquire inhibitory stimulus control. Since the reinforcer is physically identical in the two components of the multiple schedule (*i.e.*, a pellet of food), the inhibitory stimulus control of the pellet in variable time can generalize to the pellet in variable interval, and in so doing, interfere with the responding in variable interval. Second, assume that Pavlovian inhibition may be produced by associating a cue with the absence of the reinforcer. Clearly, the *mult VT VI* condition does not satisfy this criterion, whereas the *mult EXT VI* condition does. It is important to note that these two accounts are not mutually exclusive. The first account may explain negative induction (*i.e.*, the decrease below baseline response rate) and the second positive contrast (*i.e.*, the increase above baseline response rate).

It is also noteworthy that Pavlovian inhibition implies more than just reinforcement frequency reduction. The latter condition has been reported to be unnecessary for positive contrast in a number of studies (*e.g.*, Brethower and Reynolds, 1962; Wilkie, 1973). However, the absence of reinforcement frequency reduction does not imply the absence of Pavlovian inhibition. For example, consider the procedure that shifts the *mult VI VI* condition to a second *mult VI VI* condition in which the availability of the reinforcer in S1 is signalled by a novel cue (*i.e.*, *mult VI VI-mult* signalled-*VI VI*). This procedure has been reported to produce positive contrast (*e.g.*, Wilkie, 1973). By signalling the reinforcer, the compound stimulus of the S1 cue plus the novel cue is associated with the reinforcer, whereas the S1 cue in isolation is not. Consequently, Pavlovian inhibition may accrue to the S1 cue even though the reinforcement frequency in the S1 component has not changed.

The above hypothesis is similar in some respects to the hypothesis proposed by Gamzu and Schwartz (1973). According to these investigators, the *mult EXT VI* condition of Phase 2 contains a stimulus/reinforcer contingency, whereas the *mult VI VI* condition of Phase 1 does not. The stimulus-reinforcer contingency is presumed to elicit responses as in autoshaping (*cf.* Brown and Jenkins, 1968), and it is the algebraic summation (*i.e.*, additivity) of re-

sponses controlled by the response/reinforcer contingency in Phase 1 and the stimulus/reinforcer contingency in Phase 2 that is presumed to constitute the positive contrast effect. It is possible that the stimulus/reinforcer contingency in the VI component of the *mult EXT VI* condition depends on the association between the stimulus and the absence of the reinforcer in the extinction component. Thus, Pavlovian inhibition may be necessary for positive contrast because it permits the development of Pavlovian excitation. However, Gamzu and Schwartz make the additional assumptions that (1) the excitatory cue must be localized on the response manipulandum in order for the stimulus/reinforcer contingency to elicit responses, and that (2) it is two different responses that are being added together.

The first assumption is not consistent with several findings. For example, positive contrast was obtained in the present study even though the S1 and S2 cues were diffuse, and located off the response manipulandum. Furthermore, Farthing (1975) obtained positive contrast in the pigeon with S1 and S2 cues that were auditory. Thus, the localization of cues on the response manipulandum is not necessary for positive contrast.

The second assumption requires that the first one be correct. Assume instead that Pavlovian excitatory control can be added to a response that is initially under operant excitatory control. That is, positive contrast may not be a function of the additivity of responses from two different response classes, but instead, the addition of a second source of excitatory control to the initially conditioned response (*i.e.*, there is more excitatory stimulus control and hence more behavior). The latter precludes the requirement that the S1 and/or S2 cues be arranged so that responses can be produced independently of a response/reinforcer contingency (*i.e.*, the stimulus conditions necessary for autoshaping).

However, a major problem facing these and other hypotheses is that the *mult VI VI-mult EXT VI* does not always produce positive contrast (*e.g.*, Freeman, 1971; Scull and Westbrook, 1973). These failures need to be examined for two possibilities. The first is that factors other than stimulus control may be present in the altered component, and these factors can interfere with responding in the unaltered component (*i.e.*, the possible generali-

zation of inhibition across the components of the *mult* VT VI condition). The second is that Pavlovian inhibitory and/or excitatory control have not been established. The latter will require a method that can separate operant and Pavlovian sources of stimulus control, so that their relative contributions may be determined.

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