**THE EFFECT OF REINFORCEMENT DIFFERENCES
ON CHOICE AND RESPONSE DISTRIBUTION
DURING STIMULUS COMPOUNDING¹**

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In Experiments I and II, rats were trained to respond on one lever during light and another during tone. The absence of tone and light controlled response cessation. In the multiple schedule of Experiment I, all reinforcements were received for responding in tone or light; in the chain schedule of Experiment II, all reinforcements were received in no tone + no light for not responding. Experiment I subjects, for which tone and light were associated with response and reinforcement increase, responded significantly more to tone-plus-light than to tone or light alone (additive summation). Experiment II subjects, for which tone and light were associated with response increase and reinforcement decrease, responded comparably to tone, light, and tone + light. Thus, additive summation was observed when stimulus-response and stimulus-reinforcer associations in tone and light were both positive, but not when they were conflicting. All subjects in both experiments responded predominantly on the light-correlated lever during tone + light, even when light intensity was reduced in testing. Furthermore, when a light was presented to a subject engaged in tone-associated responding, all subjects immediately switched the locus of responding to the light-correlated lever. No change in locus occurred when a tone was presented to a subject engaged in light-associated responding, irrespective of the stimulus-reinforcer association conditioned to tone. The light-lever preference in tone + light indicates that the heightened responding observed in Experiment I was not the summation of tone-associated behavior with light-associated behavior. Rather, it appears to be the result of a facilitation of one operant (light-associated responding) by the reinforcement-associated cue for the other.

Key words: stimulus compounding, choice, response distribution, additive summation, multiple schedule, chain schedule, tone light, rats

When animals are trained to emit responses at a moderate rate in the presence of two independently presented stimuli, customarily a tone and a light, they typically emit more responses to the tone-plus-light compound (T+L) than to tone or light alone (Weiss, 1964, 1971, Experiment II; Wolf, 1963). This phenomenon in stimulus-compounding research has been called "additive summation" (Weiss, 1972). The present experiment explored the part played by each stimulus in the T+L compound in producing the summative effects.

In most stimulus-compounding investigations, subjects respond on the same manipulandum in tone and in light. Unfortunately, the single-lever paradigm does not readily lend itself to assessment of control by each stimulus modality when tone and light are presented together, since the locus, and frequently the pattern, of responding conditioned to tone-alone and light-alone are identical. One method of identifying the control by each stimulus is to condition responding to separate

response levers in the presence of tone and of light. Adding a new dimension, response location, to the discrimination problem may provide information about stimulus control by each modality. When tone and light are presented together, one can observe where the subject responds.

Miller (1973, Experiment II) and Meltzer and Masaki (1973) each employed a two-manipulandum paradigm, in which responding during tone was conditioned to one lever and responding during light was conditioned

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to the other, while the absence of both stimuli ($\overline{T}+\overline{L}$) controlled response cessation. Then, during T+L test presentations, responding controlled by each stimulus was independently determined by measuring response rates on each lever. In both studies additive summation was observed, with a substantial majority of subjects emitting more responses on the light-correlated lever than on the tone-correlated lever during T+L presentations. This demonstrated that light primarily controlled the locus of responding. Tone contributed mainly to the increased rate during T+L and not to response location.

Experiment I of the present study extends the findings of Miller and of Meltzer and Masaki, and analyzes factors contributing to stimulus control during T+L in the two-manipulandum paradigm. Baseline performance was similar to that in the previous studies; tone and light each controlled moderate response rates and $\overline{T}+\overline{L}$ controlled response cessation. However, stimulus-compounding tests differed from those used by Miller and by Meltzer and Masaki. In the single-lever paradigm, the type of stimulus-compounding test employed affects the magnitude of summation. When maintenance or probe tests are used, less of a summative effect is observed than when an extinction test is used (Emurian and Weiss, 1972; Weiss and Van Ost, 1974; Wolf, 1963). In the two-lever situation, Miller used a maintenance test, in which reinforcements were obtained during tone, light, and T+L test presentations. Meltzer and Masaki used a probe test, where nonreinforced test presentations of tone, light, and T+L were interspersed within a regular training session. Although additive summation was reported in both studies, its magnitude was small. To accentuate any differences in stimulus control by tone, light, and T+L the present investigators used an extinction test, in which 12 sequential block-randomizations of tone, light, and T+L, each separated by $\overline{T}+\overline{L}$, were presented without reinforcement.

Two additional tests were administered to analyze factors possibly contributing to the predominant light-lever responding during T+L observed both by Miller and by Meltzer and Masaki. Since the preference for the light lever may be a function of the particular intensities of light and of tone employed, a light-generalization stimulus-compounding test was

administered to determine if the preference for the light-correlated lever could be attenuated or reversed by decreasing the intensity of the light. A sequential-onset stimulus-compounding test was also included, whereby the tone was added to the ongoing light and the light was added to the ongoing tone. This test was used to assess whether light is only more salient than tone in determining on which lever the subject initially begins responding when tone and light are presented together, or whether light would also control response locus during T+L when the animal is responding on the tone lever at the onset of light.

EXPERIMENT I

METHOD

Subjects

Three adult male Long-Evans (hooded) rats were trained and tested at 80% of their free-feeding weights of approximately 350 g. All subjects were individually housed and had continuous access to water.

Apparatus

The chamber in which the animals worked measured 19.1 cm high by 23.5 cm long by 20.3 cm wide. The front and back walls were made of aluminum and the side walls were constructed of clear Plexiglas. The floor was composed of 0.48-cm stainless-steel rods spaced 1.3 cm apart. Two Scientific Prototype micro-switch manipulanda and a small food trough were mounted on the front wall; the two levers were 7.0 cm apart, 5.1 cm from the grid floor, and 1.9 cm from the side walls. Approximately 0.15 N downward force on a lever produced a response and an audible relay feedback. The food trough was centered between the levers 1.3 cm from the grid floor. The experimental chamber was enclosed in an Industrial Acoustics model AC-3 sound-attenuating chamber.

Two discriminative stimuli were used, a light and a tone. The light stimulus was a 100-W 115-V bulb located 7.6 cm above the chamber and covered by white translucent plastic. The light intensity, measured by a Honeywell Pentax 1°/21° photometer positioned on the grid floor, was approximately 12 foot-candles. General illumination was provided by a 15-W 115-V houselight located 7.6 cm from the chamber and covered with an

aluminum shield. The intensity of the house-light was too low to be measured by the available photometer. The tone stimulus was a 2000-Hz sine wave produced by an EICO model 377 audio generator and presented through a 10.2-cm 8-ohm speaker mounted above the back wall of the operant-conditioning chamber. Intensity of the tone was approximately 87 dB, measured by a General Radio type 1565-A sound-level meter using the C scale. The sound intensity was measured at the grid floor directly in front of the feeder trough. The ambient noise level, provided by the exhaust fan, was 70 dB.

Relay equipment, located in a room adjacent to that containing the experimental chamber, was used to arrange the scheduled contingencies. Reinforcers were Noyes 45-mg rat pellets.

Procedure

Baseline training. The subjects were trained to approach the food trough at the sound of the feeder click in Session 1. In Session 2, they were trained to press the lever and subsequently permitted to earn approximately 150 pellets on a continuous reinforcement (CRF) schedule. In subsequent sessions, food was received on a variable-interval (VI) schedule in which the first lever press occurring a specified, but variable, time after the last reinforced response produced a food pellet. The mean VI value was 15 sec in Session 3, 30 sec in Session 4, 45 sec in Session 5, 60 sec in Session 6, 75 sec in Session 7, and 90 sec thereafter. Only one lever was present in the chamber during shaping and this VI training—the right lever for S-208 and S-209 and the left lever for S-206. Next, 2 to 5-min presentations of light were alternated with 2 to 5-min of $\bar{T}+\bar{L}$. Lever pressing was not reinforced (extinction) in $\bar{T}+\bar{L}$. A response correction was imposed, so that when the 2 to 5-min $\bar{T}+\bar{L}$ period timed out, the next stimulus condition was withheld until the subject had ceased lever pressing for 10 sec. Discrimination training between light and $\bar{T}+\bar{L}$ was continued until the subject emitted at least 75% of its responses during the reinforced light components. Then, the tone stimulus was introduced. During this phase of training, only the lever that had been absent before was present. In the presence of the tone, a VI 90-sec schedule was approximated over three sessions, followed by discrim-

ination training between tone and $\bar{T}+\bar{L}$ equivalent to that previously received between light and $\bar{T}+\bar{L}$. When 75% of the subject's responses were emitted in the presence of the tone, the left and right levers were presented on alternate days (for at least six sessions). Each day, the subject received multiple VI 90-sec Extinction training; however, one day the light and light-correlated lever were present, and on the following day, the tone and the tone-correlated lever were present. $\bar{T}+\bar{L}$ always alternated with tone or light and signalled extinction.

On the final baseline schedule, both levers were present, with a VI 90-sec schedule in effect for responding on one lever during light (right lever for S-208 and S-209, left lever for S-206) and on the other lever during tone. Responses on the incorrect lever produced no scheduled consequences. Two- through 5-min presentations of tone or light were alternated with 2- to 5-min $\bar{T}+\bar{L}$ extinction components. Tone and light were presented in a nonsystematic order. Sessions lasted approximately 2.5 hr.

Discrimination and response-rate criteria. Subjects were trained on the final baseline schedule until they had met the following criteria for four consecutive days. (1) The $\bar{T}+\bar{L}$ (extinction) response rate was no more than 20% of the tone or light (VI) response rates. (2) During tone and during light, at least 75% of responses were emitted on the correct lever. (3) There was abrupt and sustained response-rate reduction on at least 75% of the $\bar{T}+\bar{L}$ presentations. (4) There was an abrupt and sustained response-rate increase on at least 75% of the tone and light presentations. (5) No increasing or decreasing trend in response rate was noted in any component. Subjects 206, 208, and 209 received 20, 36, and 23 sessions, respectively, on the terminal schedule. After satisfying these discrimination criteria, subjects were given a series of stimulus-compounding tests. Between each test, they received at least two sessions of baseline schedule training. If performance was disrupted following a test, baseline schedule training was continued until the discrimination criteria were again met before a subject was given its next stimulus-compounding test.

Extinction stimulus-compounding test. This test consisted of 2-min presentations of tone,

light, and T+L, each followed by 2 min of $\overline{T+L}$. The tone, light, and T+L stimuli were block-randomized within 12 test replications. Reinforcement was discontinued during testing, and the complete test was administered within one session, without any reinforced components interceding. Testing began after approximately 30 min of regular baseline training.

Sequential-onset stimulus-compounding test. The second test consisted of presenting a tone for 1 min and then adding a light to the existing stimulus complex (T then T+L), or presenting a light for 1 min and then adding a tone (L then T+L). These two conditions were compared to the simultaneous presentation of T+L. Subjects received six block-randomizations of 1 min of tone followed by 2 min of T+L, 1 min of light followed by 2 min of T+L and 2 min of $\overline{T+L}$. Three replications were presented on each of two consecutive days. The nonreinforced test components were interspersed within reinforced training components, with one presentation each of tone and light occurring between test stimuli. Each test presentation was followed by 2 min of $\overline{T+L}$.

Light-generalization stimulus-compounding test. The final test consisted of presentations of T+L, with the light at one of four intensities. These were produced by supplying to the bulb 120 (training intensity), 95, 70, and 45 V.

The illuminances corresponding to 120, 95, 70, and 45 V were 12.0, 6.8, 2.1, and 0.31 foot-candles respectively. Four blocks of T+L (120 V), T+L (95 V), T+L (70 V), and T+L (45 V) were presented in a block-randomized order. Two-minute presentations of the test stimuli occurred within a regular training session; that is, one presentation of the tone stimulus and the light stimulus, with reinforcement available, separated test stimulus presentations. Two replications were conducted during each of two consecutive daily sessions.

RESULTS

Terminal baseline training performance. Table 1 shows that between-session variability for responding during tone or light was less than 20% of the mean rates for Subjects 206 and 209, and was 23% for Subject 208. Few responses were emitted in $\overline{T+L}$, with response rates in tone and in light always at least five times and usually 10 times that in $\overline{T+L}$. During tone as well as light at least 90% of the total responses were emitted on the correct lever.

Extinction stimulus-compounding test. Table 2 shows that all subjects emitted substantially more responses during T+L than during tone or light presentations (additive summation). Subject 206 emitted 49.4% of total tone, light, and T+L test responses in the presence of T+L, Subject 208 emitted 48.2% to T+L,

Table 1
Terminal Training Data* (responses per minute)

		$\overline{T+L}$		<i>Tone</i>		<i>Light</i>	
		<i>Tone Lever</i>	<i>Light Lever</i>	<i>Tone Lever</i>	<i>Light Lever</i>	<i>Tone Lever</i>	<i>Light Lever</i>
A. EXPERIMENT I SUBJECTS							
Mean	206	1.3	0.2	23.6	0.1	1.0	19.2
SD		0.7	0.1	0.0	0.0	0.2	1.1
Mean	208	0.4	0.2	29.1	2.7	1.4	29.2
SD		0.2	0.1	3.4	1.9	0.6	4.9
Mean	209	1.2	2.3	29.9	1.0	1.8	39.3
SD		0.4	1.0	4.3	0.7	0.7	5.4
B. EXPERIMENT II SUBJECTS							
Mean	221	0.7	0.1	14.6	3.8	0.8	12.3
SD		0.1	0.0	0.1	0.3	0.3	1.1
Mean	222	0.1	0.1	3.6	0.2	0.0	3.7
SD		0.0	0.1	0.4	0.1	0.0	0.5
Mean	224	0.1	0.1	13.2	0.6	1.6	21.6
SD		0.1	0.0	1.1	0.2	0.3	1.7

*From final four training sessions before first stimulus-compounding test.

Fig. 1. Percentage of total test responses emitted to tone, light, and T+L during extinction tests of Experiments I and II. Data are presented individually for each subject.

and Subject 209 emitted 55.7% to T+L (Figure 1).

Table 3 indicates the percentage of test responses distributed to the light-correlated lever during tone, light, and T+L test presentations. Subjects 208 and 209 each emitted at least 95% of their T+L responses on the light-correlated lever, and S-206 emitted over 73% of these responses on the light lever. This indi-

cates almost complete control of response locus by the light.

Sequential-onset stimulus-compounding test. Table 3 shows that when tone alone was present, no subject emitted more than 11.4% of its responses on the light-correlated lever. However, when the light was added to the tone, each subject switched levers almost immediately and emitted at least 90.9% of its responses on the light-correlated lever. In contrast, when a tone was added to an already present light, all subjects continued to respond predominantly on the light-correlated lever, although for each subject the percentage of responses on the light-correlated lever was slightly lower after the tone was added than before (see Table 3). Still, no less than 84.4% of the T+L responses (when a tone was added to a light) were emitted on the light-correlated lever. Response rates for individual subjects in the presence of each stimulus during the sequential-onset test show that T+L did not control additive effects as consistently here as

Table 2

Extinction stimulus-compounding test results (total responses per minute emitted on both levers).

Subject	Stimulus Condition			
	T+L	Tone	Light	T+L
EXPERIMENT I				
206	0.3	8.8	7.6	16.0
208	0.2	23.2	14.4	35.0
209	0.5	15.0	19.1	42.9
EXPERIMENT II				
221	3.9	15.8	13.5	10.5
222	0.3	4.5	3.3	2.2
224	2.3	12.1	22.8	23.3

Table 3

Percentage of test responses emitted on the light-correlated lever during each stimulus condition.

Subject	Extinction Test			Sequential-Onset Test			Light-Generalization Test			
	Tone	Light	T+L	T/T+L	L/T+L	T+L	120 V	95 V	70 V	45 V
A. EXPERIMENT I										
206	1.5	96.1	73.8	0/90.9	99.1/84.4	94.0	89.5	86.4	75.2	68.5
208	0.3	89.6	93.4	8.7/91.3	98.3/96.6	97.1	93.9	90.4	88.3	95.1
209	4.9	99.3	97.0	11.4/93.3	98.4/94.5	91.6	91.9	97.4	97.9	91.0
B. EXPERIMENT II										
221	28.6	94.4	90.1	15.0/74.6	83.3/91.3	88.1	100	100	85.0	56.9
222	13.3	100	100	0/100	100/92.4	100	100	100	88.9	54.5
224	18.0	87.4	85.8	0/76.2	94.5/77.6	80.9	80.4	80.7	77.4	87.8

Table 4
Sequential-onset stimulus-compounding test results (responses per minute emitted on each lever).

Subject	T -----> T+L				L -----> T+L			
	Tone Lever	Light Lever	Tone Lever	Light Lever	Tone Lever	Light Lever	Tone Lever	Light Lever
A. EXPERIMENT I								
206	20.2	0	1.7	16.7	0.2	17.7	3.0	16.3
208	33.2	3.2	6.3	66.4	1.0	57.8	2.4	68.3
209	29.8	3.8	3.0	41.8	0.7	41.5	2.3	38.4
B. EXPERIMENT II								
221	11.3	2.0	3.3	9.6	1.7	8.3	1.3	13.5
222	4.8	0	0	2.9	0	3.7	0.2	2.3
224	14.0	0	5.3	16.8	1.3	22.7	4.6	15.9

when tone and light were presented simultaneously in the extinction tests (Table 4). However, it is difficult to evaluate additive summation in this instance, as conditions were not comparable between tone-alone or light-alone and T+L. Stimulus durations differed. Also, the onset of tone or light followed $\overline{T+L}$, while the onset of T+L followed tone or light.

Light-generalization stimulus-compounding

test. When the light was illuminated at various intensities during T+L presentations, all subjects continued to respond predominantly on the light-correlated lever (Table 3). Only Subject 206 showed a systematic decrement in percentage of responses emitted on the light-correlated lever as the intensity of the light decreased. Even with this decrement, the majority of T+L responses was always emitted

Fig. 2. Total responses per minute emitted on both levers during each of the four light intensities of the light-generalization test. See method for illuminances corresponding to the indicated voltages. Data are presented for each subject in Experiments I and II.

on the light-correlated lever at every light intensity employed.

Figure 2 shows total response rates (across both levers) of each subject during the light-generalization test. All subjects showed a somewhat systematic decrease in response rate as light intensity became less similar to the intensity present during training (120 V), with Subjects 206 and 208 showing a drastic reduction in total response rates when tone was combined with the 45-V light.

DISCUSSION

Additive summation was observed for all three rats during the extinction stimulus-compounding test. In addition, all subjects responded primarily on the light-correlated lever when T+L was presented in the extinction, sequential-onset, and light-generalization stimulus-compounding tests. These results support the findings of Miller (1973) and of Meltzer and Masaki (1973).

The present investigators found a larger additive effect during T+L stimulus conditions than did either Miller or Meltzer and Masaki, despite similar training conditions. Using a probe test, whereby nonreinforced test-stimulus presentations were interspersed with training conditions, Meltzer and Masaki found that an average of only 40.9% of the test responses were emitted during T+L. Miller employed a maintenance test in which responding was reinforced during tone, light, and T+L test presentations. He observed the weakest additive summation, with only 35.7% of test responses emitted during T+L. Although there was a larger average percentage of responses emitted to T+L than to tone or light (additive summation) using each testing procedure, the magnitude of the effect appears to depend on the type of test employed. This is consistent with findings in the single-lever paradigm mentioned in the introduction.

The results of Miller, Meltzer and Masaki, and those of the present experiment show that subjects respond predominantly on the light-correlated lever when T+L is presented in this two-manipulandum stimulus-compounding paradigm. This indicates that the saliency of the light stimulus over the tone stimulus in controlling response locus is an extremely robust phenomenon observed under the wide range of stimulus parameters and methods em-

ployed in these experiments. It thus seems unlikely that the light-lever preference observed in the present study could be attributed to any stimulus biases that might have developed through all subjects receiving initial training to the light.

Further evidence for the extreme control by the light stimulus was accrued through the sequential-onset and light-generalization stimulus-compounding tests. Results of the sequential-onset test demonstrated that the light determined which lever the subject went to during T+L (1) following a period of response cessation ($\bar{T}+\bar{L}$), and (2) when it was already responding on the tone-correlated lever in tone. While Miller (1973, Experiment 4) and Thompson and Hoesen (1967) both obtained results indicating that tone may become the dominant component in a T+L compound by manipulating light intensities during training, the present light-generalization test results suggest that if during training the light becomes dominant it will remain so even when the intensity is reduced.

The results of these stimulus-compounding tests reveal the extreme dominance of the light as compared to the tone in controlling locus of responding. But control of responding by the tone during T+L presentations was profound. All subjects emitted more than twice the number of responses to T+L than to light alone. This indicates that the heightened responding observed during T+L is *not* the summation of tone-associated behavior and light-associated behavior. Rather, it appears to be the result of a facilitation of one operant (light-associated responding) by the cue for the other.

EXPERIMENT II

Experiment I showed that stimulus-compounding results obtained in a single-lever situation are replicable in a two-lever paradigm; that is, when tone and light are each correlated with an increase in response rate and reinforcement density relative to $\bar{T}+\bar{L}$, additive summation is observed in T+L. In the single-lever paradigm, each stimulus is associated with a certain reinforcement density and a specific response rate. In the two-lever paradigm, a unique response location is also associated with each stimulus. Experiment I demonstrated that this additional discriminative requirement, response location, did not change

the outcome of stimulus compounding. In both the one- and two-lever situations, more responding was observed during T+L than during tone or light alone.

Response rate and reinforcement density generally covary in stimulus-compounding studies: tone and light are customarily each associated with an increase in response rate and reinforcement density relative to these values in $\bar{T}+\bar{L}$. Consequently, the separate contributions of stimulus-reinforcer (S-S^R) and stimulus-response (S-R) associations to additive summation cannot be determined. Weiss (1971) and Weiss and Van Ost (1974) confronted this problem by manipulating relative reinforcement density between components of a multiple schedule, while holding relative response rate constant.

Weiss and Van Ost compared two groups of rats. Group 1 subjects were trained on a multiple schedule in which bar pressing during tone and during light was intermittently reinforced, and refraining from bar pressing during $\bar{T}+\bar{L}$ was periodically reinforced. In this schedule, tone and light each became associated with an increase in response rate, but no change in reinforcement density, relative to $\bar{T}+\bar{L}$. Group 2 subjects responded on a chain schedule. Bar pressing during tone and light only served to produce $\bar{T}+\bar{L}$, where the rats received food if they refrained from bar pressing. Thus, tone and light each came to control an increase in response rate while signalling a decrease in reinforcement density, relative to $\bar{T}+\bar{L}$. During stimulus compounding, Group 1 subjects emitted more responses to T+L than to tone or light, while Group 2 subjects did not. Therefore, in a single-lever design, when S-R and S-S^R associations worked in opposition to each other, that is, tone and light each signalled a response-rate increase but reinforcement decrease, additive summation was not observed. Would this also be true in a two-lever paradigm?

The present study employed a chain schedule similar to that used by Weiss and Van Ost (1974). The main difference was that tone and light controlled responding on separate levers, rather than one lever. This tested the generality of Weiss and Van Ost's findings in a situation that permitted the assessment of the relative contribution of each stimulus to response control during T+L presentations.

METHOD

Subjects

Three adult male Long-Evans (hooded) rats were trained and tested at 80% of their 350-g free-feeding weights. All subjects were individually housed and had continuous access to water.

Apparatus

The apparatus employed was the same as that used in Experiment I.

Procedure

Baseline training. On Day 1, subjects were magazine trained in the presence of $\bar{T}+\bar{L}$ and shaped to press the lever in the presence of light. During shaping, a response was reinforced by the immediate offset of light and presentation of a food pellet. Following shaping, the subjects were put on a chain CRF DRO 2-sec schedule, whereby one response terminated the light stimulus and pellets were delivered every 2 sec during $\bar{T}+\bar{L}$, provided the subject had not pressed the bar for 2 sec. One to three pellets were dispensed during $\bar{T}+\bar{L}$ before the light was again illuminated. Both levers were present in the chamber during initial training, although only the light-correlated lever was operative. For S-221 and S-222, the right lever was correlated with light; for S-224, the left lever was correlated with light. A chain VI 30-sec DRO 28-sec schedule was gradually approximated by increasing the S₂ (initial) link of the chain from CRF to VI 15-sec to VI 22-sec to VI 30-sec. Concurrently, the S₁ (terminal) link schedule was increased from DRO 2-sec to DRO 28-sec in 2- to 5-sec increments. Approximately five sessions were utilized to approximate the chain VI 30-sec DRO 28-sec schedule. Next, the light-correlated lever was removed from the chamber and responses on the tone-correlated lever were reinforced according to a chain VI 30-sec DRO 28-sec schedule for three sessions. Then, the light lever was replaced in the chamber. The subject was on a chain VI 30-sec DRO 30-sec schedule, with tone being presented in the S₂ link of the chain until 75% of the responses were emitted on the tone-correlated lever. When this discrimination criterion was met, the subject was put on a chain VI 30-sec DRO 30-sec schedule with light presentations as the S₂ link of the

chain. As with the tone, the light stimulus was presented until 75% of responding during light was on the light-correlated lever. Subsequently, tone and light presentations were alternated across sessions (for at least three sessions of tone and three sessions of light), before both stimuli were presented, separately, during the same session. The VI 30-sec schedule during the S_2 components was increased to VI 60-sec for all subjects, but due to decrements in response rate, was returned to VI 30-sec for Subjects 222 and 224.

The final training schedule was a chain VI 30-sec DRO 30-sec for Subjects 222 and 224 and a chain VI 60-sec DRO 30-sec for Subject 221. Tone and light were randomly alternated as the stimulus present during the S_2 link of the chain, while $\overline{T+L}$ was always associated with the S_1 link. $\overline{T+L}$ durations varied so that the subject could obtain from zero to three reinforcements before returning to the S_2 link (tone or light).

Discrimination and response-rate criteria. Subjects were trained on the final baseline procedure until the same criteria were met as specified in Experiment I. Subjects 221, 222, and 224 received, respectively, 20, 32, and 26 days of training on their terminal baseline schedules before testing.

Extinction stimulus-compounding test. This test was similar to the extinction stimulus-compounding test described in Experiment I, except that subjects here received 45 to 50-sec presentations of tone, light, and T+L test stimuli separated by 15-sec presentations of $\overline{T+L}$. The shorter test components were used in Experiment II to keep test conditions consistent with training conditions. It was felt that longer test components would be disruptive to stimulus control. During tone, light, or T+L, if the subject responded on either lever between 45 and 50 sec after stimulus onset, that response terminated the stimulus condition. Otherwise, the stimulus condition was automatically terminated at 50 sec.

Sequential-onset stimulus-compounding test. Six randomized blocks of tone followed by T+L, light followed by T+L, and T+L were presented as in Experiment I. To keep test conditions consistent with training procedures, this test differed in several ways from that in Experiment I. Stimulus durations were shortened; 30 sec of tone or light was followed by

45 to 50 sec of T+L. Additionally, the first response on either lever after 45 sec of T+L produced 15 sec of $\overline{T+L}$. If no response occurred, T+L was automatically terminated at 50 sec, and 15 sec of $\overline{T+L}$ ensued.

Light-generalization stimulus-compounding test. Four randomized blocks of T+L (120 V), T+L (95 V), T+L (70 V), and T+L (45 V) were presented as in Experiment I, with the following differences. Each T+L presentation lasted 45 to 50 sec with the first response after 45 sec producing 15 sec of $\overline{T+L}$. In the absence of responding, T+L automatically terminated at 50 sec. All four replications of this test were administered during a single session.

RESULTS

Terminal baseline training performance. Table 1 shows the mean responses per minute across the final four training sessions before testing. The between-session variability, represented by the SD, of responding during tone or light was less than 20% of the mean response rates for all subjects. Responding during $\overline{T+L}$ was extremely low, always being less than 10% of response rates during tone or light. Subjects 222 and 224 emitted at least 90% of their tone and their light responses on the correct lever, while Subject 221 emitted at least 75% of its responses on the correct lever. Although training response rates were higher during tone and light presentations for subjects in Experiment I than for subjects in Experiment II, there was some overlap between Subjects 206 and 224.²

Further comparisons of baseline performance for subjects in Experiments I and II indicate several similarities. (1) In each experiment, one subject showed a consistently higher response rate during tone than during light (see Subjects 206 and 221). (2) One subject from each experiment showed equivalent response rates during light and tone (see Subjects 208 and 224). (3) One subject in each experiment showed a higher rate during light than during tone (209 and 224). Finally, (4) Table 1 also shows substantial overlap between subjects of the two experiments in degree of discrimination. This is revealed by the re-

²Several subjects in the Meltzer and Masaki (1973) study, which was similar in procedure and results to Experiment I, also had response rates equivalent to those of the subjects in Experiment II of the present study.

sponse rates during $\overline{T}+\overline{L}$ and the amount of responding on the incorrect lever during tone and light components.

Extinction stimulus-compounding test. Table 2 shows that Subjects 221 and 222 emitted fewer total test responses to T+L than to either tone or light. Subject 224 showed almost equal response rates in light and in T+L, with its lowest response rate in tone. The percentage of total test responses emitted to T+L is clearly less for every subject in Experiment II than for any subject in Experiment I (Figure 1). Also, no subject in Experiment II showed additive summation, while every subject in Experiment I showed substantial additive effects. A significantly greater percentage of total test responses was emitted to T+L by the Experiment I subjects (51.5%) than by the Experiment II subjects (29.5%) ($t_{(4)} = 3.72$, $p < 0.05$).

During T+L presentations, all Experiment II subjects distributed at least 85% of their responses to the light-correlated lever (see Table 3). Subject 222 responded exclusively on the light-correlated lever during both light and T+L test components, while Subjects 221 and 224 emitted a slightly smaller percentage of T+L responses than light responses on the light-correlated lever. No consistent difference is observable between the allocation of T+L responses between levers for the subjects in Experiment I (88.1%) and the subjects in Experiment II (92.0%), $t_{(4)} = 0.47$.

Sequential-onset stimulus-compounding test. When the light stimulus was added to an ongoing tone stimulus, each subject immediately shifted to the light-correlated lever, as had the Experiment I subjects (see Tables 3 and 4). When tone was added to an already present light, all subjects continued to respond predominantly on the light-correlated lever. Subject 221 even emitted a greater percentage of responses on the light-correlated lever after tone had been added to the light than when light was presented alone.

Light-generalization stimulus-compounding test. Two of the three subjects showed a systematic decrease in the percentage of T+L responses emitted to the light-correlated lever as the intensity of the light was lowered (see Table 3). The light intensity had no systematic effect on distribution of responses between levers for the third subject (224). As had Experiment I subjects, even at the lowest light intensity, Ex-

periment II subjects continued to distribute the majority of their T+L responses to the light-correlated lever. Nevertheless, at the lowest light intensity (45 V), Experiment II subjects responded more on the tone-correlated lever than Experiment I subjects. Two of the three Experiment I subjects emitted more than 90% of T+L responses on the light-correlated lever when light was at 45 V. In contrast, two of the three Experiment II subjects emitted only slightly more than half of their T+L (45 V) responses on the light-correlated lever.

Another dissimilarity between Experiment I and Experiment II subjects during the light-generalization test can be seen in Figure 2. Each subject in Experiment I showed at least some tendency toward a systematic decrease in total response rate as light intensity decreased. This is characteristic of light-generalization gradients when no tone is present. In contrast, Experiment II subjects showed relatively flat gradients across light intensities. While all subjects in Experiment I revealed substantially lower response rates during T+L (45 V) than during T+L (120 V), two of the three subjects in Experiment II had a higher total response rate during T+L (45 V) than during T+L (120 V).

DISCUSSION

The present findings show that when tone and light are correlated with increased responding but decreased reinforcement relative to $\overline{T}+\overline{L}$ (positive S-R associations but negative S-S^R associations), additive summation is not observed during T+L test presentations. These results support and extend the findings of Weiss and Van Ost (1974). The mean percentage of tone, light, and T+L test responses emitted to T+L was 51% in Experiment I and only 29.5% in Experiment II. In comparison, the percentage of test responses distributed to T+L by the chain schedule subjects of the Weiss and Van Ost single-lever study was 27%. This suggests that under similar schedules of reinforcement, animals show similar performance in the single-lever and two-lever situations.

The extinction and sequential onset tests did not reveal an effect of S-S^R associations on response location during T+L. Nevertheless, results of the light-generalization test suggest that at low light intensities, tone may have differentially controlled responding in Experi-

ments I and II. When the light was presented at the lowest level (45 V), subjects in Experiment I continued to respond on the light-correlated lever, emitting a mean of 85% of T+L responses on that lever. Conversely, Experiment II subjects tended to distribute more responses to the tone-correlated lever; only 66% of T+L responses were emitted on the light-correlated lever. These data suggest that at some stimulus intensities, S-S^R associations may affect response location as well as response rates during T+L. Further research is needed to explore this possibility.

GENERAL DISCUSSION

The predominant light-correlated responding in Experiments I and II showed that tone and light differentially controlled responding during stimulus compounding. In both experiments, light controlled the locus of responding during T+L. However, the enhanced T+L responding in Experiment I suggests that tone facilitated light-correlated responding. These results indicate that additive summation here was not the direct combination of two operants, that is, tone-associated and light-associated responding. Instead, it appears to be the facilitation of one operant by the cue for another.

In both experiments, rats produced moderate response rates during tone and during light and ceased responding in $\overline{T}+\overline{L}$. Thus, S-R associations were invariant over the two experiments. In contrast, S-S^R associations differed between Experiments I and II. Tone facilitated light-associated responding during T+L when tone was correlated with an increase in reinforcement (positive S-S^R associations) but not when it was correlated with a decrease in reinforcement (negative S-S^R associations). This indicates that S-S^R associations to tone influenced the facilitation of light-correlated responding in T+L. S-S^R associations of light covaried with those of tone. This may be important for the resultant T+L behavior. To assess fully the contribution of S-S^R associations during tone to the facilitation of light-correlated operant responding, the presence or absence of reinforcement in tone should be manipulated independently of that in light.

Results similar to those of the present investigation have been reported in transfer-of-

control experiments suggested by two-process learning theories. In one type of transfer experiment, an operant response is reinforced in the presence of one stimulus, and the same reinforcer is noncontingently presented during a second stimulus. When the two stimuli are presented together, the stimulus correlated with noncontingent reinforcement facilitates the operant performance conditioned to the first stimulus (Trapold and Winokur, 1967). This is often interpreted as showing that S-S^R associations affect operant performance. Unfortunately, both food-cup approach responses and adventitiously reinforced responses acquired during the noncontingent reinforcement periods may mediate in strengthening the specific operant under investigation (Trapold and Overmier, 1972). To surmount this problem in interpretation, many investigators have tried to control for possible operant mediation effects. Trapold and Carlson (1965) placed the food cup distal to the lever so that food-cup approach responses would be incompatible with lever pressing. Response facilitation was still obtained. Trapold and Farlie (1965) explicitly trained an operant response that should have enhanced the facilitation, but found no difference between those subjects and subjects that did not receive this training. Grossen, Kostansek, and Bolles (1969), using an avoidance paradigm, trained an operant which, according to an operant mediation hypothesis, should have reduced the effects of S-S^R pairing on the operant being investigated, but still obtained the usual effects.

The present paradigm provides a new method of controlling for response-mediation factors while investigating the influence of S-S^R associations on operant performance. S-S^R associations were varied, while maintaining the same operant response. A similar behavior was conditioned to tone in Experiments I and II, that is, pressing lever A. Additionally, that operant was incompatible with the light-correlated operant, pressing lever B. Despite the similarity of the tone-correlated response in Experiments I and II, tone enhanced light-correlated responding when tone provided positive S-S^R associations, but did not enhance responding when it provided negative S-S^R associations. This suggests that S-S^R associations are important in determining operant behavior, thus supporting a two-process learning theory.

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