COMPOUNDING OF DISCRIMINATIVE STIMULI THAT MAINTAIN RESPONDING ON SEPARATE RESPONSE LEVERS¹

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In Experiment 1, rats' responses were reinforced on a fixed-interval 30-sec schedule in the presence of either a light or a tone and were not reinforced in their absence. Each stimulus was correlated with its own response lever, with only one lever present during a session. When light and tone were compounded in the presence of the tone-correlated lever, no change in responding occurred. However, when tone was compounded with light in the presence of the light-correlated lever, level of responding was greater than to light alone (response summation). Summation was also found when each stimulus was correlated with the same lever. Next, light and tone were again correlated with separate levers, but both levers were always simultaneously present. Compounding produced both summation and emission of most responses on the light-correlated lever. This prepotency of light was reduced (1) by leaving a houselight on throughout the session; and (2) by correlating each stimulus with a different schedule (either fixed-interval 4.7-sec or fixed-interval 30-sec). With a medium- and high-intensity houselight and with the different reinforcement schedules, similar results were obtained during compounding, regardless of whether compounding occurred in the presence of the light- or tone-correlated lever.

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Stimulus compounding is typically studied by first correlating two discriminative stimuli (S^Ds) with the same schedule of positive reinforcement and not presenting reinforcement in the absence of either stimulus (S^A). When stimulus control over responding is obtained, combining the separate S^Ds will produce a greater level of responding than is maintained by either S^D (e.g., Wolf, 1963; Weiss, 1964). In all instances in which this response summation

has been demonstrated the response is always emitted on the same operandum in the presence of each S^D and the compound. While adequate for demonstrating summation, this procedure reveals nothing about each S^D's contribution to the level of responding maintained by the compound, because it is impossible to separate the effects of each S^D with only a single lever. Experiment 1 examined these considerations by having each S^D maintain responding on its own lever and then combining the S^Ds while subjects responded on one of the levers.

In addition, for one group of subjects, each S^D was correlated with a different operant chamber and physically different response lever. The other group of animals was trained in the same box and each lever was physically identical. This was done to see if the stimulus context within which each S^D occurred would affect responding during compounding. For subjects trained in separate boxes, this context would change during compounding when one of the S^Ds is presented while subjects are responding in the other box in the presence of the other stimulus. For subjects trained in the same operant box, the stimulus context remains constant during compounding.

¹Experiment 1 was presented at the 1972 meeting of the Western Psychological Association. Reprints may be obtained from the author, Department of Psychology, Western Washington State College, Bellingham, Washington 98225.

EXPERIMENT I: S^Ds CORRELATED WITH SEPARATE LEVERS

METHOD

Subjects

Twelve male Holtzman albino rats, 150 days of age, were maintained at 80% of free-feeding weight during the experiment.

Apparatus

Grason-Stadler single-lever and double-lever operant chambers were used. The lever in the single-lever box measured 5.1 by 1.5 by 1.5 cm (2 by 0.5 by 0.5 in.), was colored silver, rounded at the front edge, and was located in the middle of the right side wall. A force of 0.147 N (15 g) was required to depress the lever. Two identical retractable levers, manufactured by Environmental Sciences Corporation, were used in the two-lever box. Each lever measured 4.0 by 1.5 by 1.5 cm (1.5 by 0.5 by 0.5 in.), was colored gold, and was rectangular in shape. Each lever was located 4.3 cm (1.75 in.) to the left or right of the middle of the right side wall. A force of 0.343 N (35 g) was necessary to depress the lever.

Light and tone were used as the S^Ds. The light's intensity was 61.6 cd/m² (18.0 ft candles). Frequency and amplitude of the tone were, respectively, 1500 Hz (re: 0.0002 dynes/cm²) and 8 dB above the 74-dB ambient noise level. All measurements were made at each lever in each box. In the two-lever box, the speaker for the tone was placed 6.7 cm (2.5 in.) above the Plexiglas roof, 10.5 cm (4 in.) out from the right side wall, and equidistant (17.8 cm) (7.5 in.) from each lever. The light was placed directly underneath the speaker. These same locations of the stimuli were maintained in the single-lever box, with the light and tone sources placed the appropriate distance to the left of the single lever.

Procedure

The Miller and Ackley (1970) procedure for studying summation was used. Responses were reinforced on a fixed-interval (FI) 30-sec schedule only in the presence of light or tone. Absence of the S^Ds signalled no reinforcement (S^A). A period of S^A occurred after each FI presentation. Onset of light or tone initiated the FI and the first response that occurred at the end of 30 sec produced a single 45-mg

Noyes pellet, terminated the S^D, and began the S^A period. Duration of S^A was randomly varied so that the subject could not use reinforcement as a cue to estimate the beginning of the next FI presentation. Average duration of S^A was 35 sec, with a range of 15 to 55 sec. Any responses emitted during S^A stopped the tape programmer, which timed the S^A interval, for 10 sec. Any other responses emitted during this 10-sec period recycled the interval. Daily sessions lasted 1.5 hr.

Subjects 1 to 6 were given discrimination training in each operant box on alternate days. Only the right lever was extended in the two-lever box for these subjects. For Subjects 1 to 3, tone was correlated with the single-lever box and light was correlated with the two-lever box. For Subjects 4 to 6 the reverse was true. Subjects 7 to 12 were trained in only the two-lever box. The right or left lever was exposed on alternate days and the other lever remained retracted. For Subjects 7 to 9, the left lever was correlated with tone and the right lever with light; the opposite was true for Subjects 10 to 12. The animals were maintained on this schedule for 30 days, by which time discrimination between S^D and S^A had developed. At least 10 times as many responses were emitted during S^D presentations as during S^A presentations.

Light and tone were then compounded during FI presentations when only the one S^D normally appeared. Compound tests were presented over two days. Subjects 1, 2, and 4 were tested first in the single-lever box and then in the double-lever box on Day 2; Subjects 3, 5, and 6 were tested in reverse order. Subjects 7, 8, and 10 were tested first with the right lever extended in the two-lever box and then with the left lever extended on Day 2; Subjects 9, 11, and 12 were tested in opposite order. During compounding, the stimulus correlated with the box or lever that was absent was combined with the stimulus that was maintaining responding on its correlated lever. Six compound presentations randomly occurred on each of the two test days, on the average of every sixth FI presentation. Responding was reinforced during compound presentations.

Following this testing, subjects were given further discrimination training, but now with each S^D associated with the same single lever. Subjects 1 to 6 were presented with both light and tone in the single-lever box; Subjects 7 to

12 were presented with both light and tone in the two-lever box, with only the right lever extended. Light and tone were presented about equally in random fashion each session. The rats were run for 15 days. Light and tone were then compounded six times during one test session, to see if summation would occur in the standard single-lever situation.

RESULTS

Mean number of responses emitted by each subject during each S^D and the compound during each test session is shown in Table 1. The left part of the table (columns 2-5) presents the results obtained when each S^D was associated with a separate lever. The right part (columns 6-8) presents the results obtained when light and tone were correlated with the same lever. The corresponding combined data

for Subjects 1-12 are shown in Figure 1, panels A and B, respectively.

Response frequency during compounding is also expressed in terms of a per cent increase or decrease in responding compared to the single S^D (see column 5 of Table 1). For example, Subject 1 emitted a mean of 32.2 responses during tone presentations and 26.7 responses during compounding while responding on the tone-correlated lever. Thus, $26.7 - 32.2/32.2 = -17.1\%$, a drop in responding during compounding. This same animal emitted a mean of 36.7 responses during light presentations and 42.7 responses during compound presentations while responding on the light-correlated lever. Thus, $42.7 - 36.7/36.7 = +16.3\%$, a gain in responding during compounding. For purposes of comparison and discussion, an increase or decrease of 0 to 15%

Table 1

Mean number of responses emitted during the test sessions by each subject on the levers correlated with tone or with light and to the compound formed by presenting the S^D correlated with the other lever is shown in columns 2-4. Single and compound stimuli compared in terms of a per cent increase or decrease in responding to the compound are presented in column 5. The data for the single and compound stimuli, when both stimuli were correlated with the same single lever, are shown in columns 6-8. Each mean is based on the total number of responses emitted over all presentations of that particular stimulus during each test session.

Subject column →	<i>S^Ds Correlated With Separate Levers</i>				<i>S^Ds Correlated With Same Lever</i>		
	<i>Light-Correlated Lever</i>	<i>Tone-Correlated Lever</i>	<i>Compound</i>	<i>Per Cent Change</i>	<i>Light</i>	<i>Tone</i>	<i>Compound</i>
	2	3	4	5	6	7	8
1	— 36.7	32.2 —	26.7 42.7	-17.1 +16.3	24.3	26.6	30.7
2	— 70.9	45.8 —	39.0 68.8	-14.8 - 3.0	62.2	58.7	70.4
3	— 20.7	11.5 —	15.2 28.3	+32.2 +36.7	25.5	32.0	37.8
4	— 28.6	17.1 —	29.0 41.0	+70.0 +43.3	24.6	15.1	31.7
5	— 16.3	30.4 —	25.7 29.2	-15.5 +79.1	23.8	28.9	33.2
6	— 6.3	6.4 —	5.0 8.2	-21.9 +30.2	5.7	5.5	5.0
7	— 12.4	9.8 —	10.5 21.5	+ 7.1 +73.4	14.0	13.4	18.0
8	— 30.8	26.2 —	23.7 45.5	- 9.5 +47.7	33.0	28.3	39.7
9	— 31.5	21.2 —	20.3 41.0	- 4.2 +30.2	22.2	21.6	33.3
10	— 46.6	51.7 —	52.7 51.8	+ 0.2 +11.2	43.5	45.0	50.7
11	— 33.5	44.0 —	36.0 52.7	-18.2 +57.3	32.1	32.8	35.3
12	— 3.4	6.4 —	4.5 4.8	-29.7 +41.2	4.4	3.1	2.4

is considered small, from 16 to 35% is considered moderate, and beyond 35% is considered large.

Where each S^D was associated with separate levers, group data were analyzed with a three-factor analysis of variance: training in same *vs* different operant boxes; compounding in the presence of the tone- *vs* light-correlated lever; frequency of responding during single *vs* compound S^D presentations (Winer, 1962, p. 319). The Newman-Keuls test was used to test the significance of appropriate *post hoc* comparisons.

Fig. 1. Mean number of responses emitted by Subjects 1 to 12 combined during single and compound S^D presentations, as a function of which lever and its correlated S^D was present during single S^D presentations, is shown in panel A. Each S^D was correlated with its own lever. Mean number of responses emitted to light, tone, and their compound by Subjects 1 to 12, when each S^D was correlated with the same lever, is shown in panel B.

The analysis indicated no significant difference ($F(1,10) < 1.0$, $p > 0.25$) due to training in the same or different operant boxes. However, a significant interaction ($F(1,10) = 17.1$, $p < 0.01$), shown in panel A of Figure 1, was found between responding maintained by the single and compound S^D s as a function of which lever was present during compounding. Compounding S^D s while subjects responded on the tone-correlated lever produced no significant change ($p > 0.25$) in responding compared to tone presentations. The majority of animals (Subjects 1, 2, 5, 6, 8, 9, 11, and 12) emitted fewer responses to the compound than to the tone (compare columns 3 and 4 of Table 1). This decrease was small for Subjects 2, 8, and 9 and moderate for Subjects 1, 5, 6, 11, and 12. Subjects 3, 4, 7, and 10 did emit more responses to the compound than to the tone; this difference was very small for Subjects 7

and 10, moderate for Subject 3, and large for Subject 4.

However, compounding S^D s while subjects responded on the light-correlated lever produced a significant increase ($p < 0.05$) in responding compared to light presentations (compare columns 2 and 4). The majority of rats (Subjects 1 and 3 to 12) emitted more responses during compounding than during light. This increase was small for Subject 10, moderate for Subjects 1, 6, and 9 and large for Subjects 3, 4, 5, 7, 8, 11, and 12.

When the animals were tested in the standard single-lever situation, with both S^D s associated with the same lever, significantly more responses ($F(2,22) = 6.6$, $p < 0.01$) were emitted during compounding. The compound maintained a significantly higher level of responding than did either tone or light ($p < 0.01$ and < 0.05 , respectively). Ten animals (Subjects 1 to 5 and 7 to 11) emitted more responses during compounding than during either single S^D presentation (compare columns 6 and 7 with column 8).

DISCUSSION

Compounding S^D s that maintained responding on the same lever produced a higher frequency of response than was maintained by the single S^D s. However, when each S^D was correlated with its own response lever, this response summation was consistently found only when compounding occurred while subjects responded on the light-correlated lever. Compounding S^D s while subjects responded on the tone-correlated lever produced no overall change in responding and reduced responding in the majority of cases. These results suggest complex interactions between S^D s during compounding which are assessable only when the S^D s and their correlated responses are separated.

It is also apparent that responding during compounding was not affected by the context within which light and tone were presented. Subjects 1 to 6 responded in different operant boxes and on different levers in the presence of each S^D ; Subjects 7 to 12 responded in the same operant box and on physically identical levers during each S^D presentation. Both groups exhibited essentially the same pattern of responding during compounding. This result suggests that the effects of the separate S^D s transferred and were maintained despite a

change in context for one of the S^Ds. However, Miller and Price (*in press*) have shown that if the responses maintained by each S^D and/or the context within which the responses are performed are markedly dissimilar (*e.g.*, running in a straight alley and lever pressing in an operant box), then the magnitude of the effects reported here is substantially reduced when the S^Ds are combined.

The results of this first experiment also do not seem to be limited to a lever-pressing situation. Miller, Waibel, and Pudelko (1969) found analogous results with an instrumental avoidance situation. Rats were trained to avoid shock by either running to the other side of a shuttle box in the presence of a buzzer or remaining where they were in the presence of light. The opposite conditions held when subjects were on the other side of the box. Compounding light and buzzer on the side on which the rats ran to the buzzer and stayed to the light produced a greater latency of response than occasioned by buzzer alone. However, compounding the stimuli on the side on which subjects ran to the light and stayed to the buzzer produced a significantly shorter latency than produced by light alone.

EXPERIMENT II: SEPARATE LEVERS ASSOCIATED WITH EACH S^D AND BOTH LEVERS CONCURRENTLY AVAILABLE

In this experiment, subjects again responded on separate levers in the presence of light and tone. However, during both single and compound S^D presentations, both levers were always available. It was felt that subjects' distribution of responses on each lever during compounding might clarify the results found in the first experiment.

METHOD

Six different rats (Subjects 13 to 18) were used, as was the two-lever operant box. Both light and tone S^Ds were presented during a session. Subjects were maintained on FI 30-sec in the presence of light or tone, and periods of S^A alternated with the S^Ds. During training and testing, both levers remained extended. For Subjects 13 to 15, the right lever was associated with tone and the left lever with light; for Subjects 16 to 18 the reverse was

true. Responses emitted on the incorrect lever during light or tone presentations were not penalized, but subjects had to emit one response on the correct lever after the interval timed out in order to receive reinforcement. Light and tone were presented in random order and occurred about equally often during each 1.5-hr session.

Subjects were trained with this procedure for 30 days. By this time, they both confined their responding to S^D presentations and emitted nearly all their responses on the appropriate lever in the presence of each S^D (see columns 5 and 6 of Table 2). During compound tests, light and tone were combined six times each session during periods when only the single stimuli normally occurred. Testing was carried out over two days, for a total of 12 compound presentations. Reinforcement could be obtained by responding on either lever during compound presentations.

RESULTS

Mean number of responses emitted by each animal during each stimulus is shown in Table 2. Data for Subjects 13 to 18 for the two tests days combined are illustrated in Figure 2. Since the responses emitted on the incorrect lever during single S^D presentations did occur while the rats responded in the presence of a particular S^D, these responses were added to the number of responses emitted on the correct lever. The means for light and tone thus represent the sum of the responses emitted on both the correct and incorrect levers.

During compounding, subjects emitted significantly more responses ($F(1,5) = 41.1$, $p < 0.01$) on the lever correlated with light (see Figure 2 and compare columns 7 and 8 of Table 2). Except for Subject 14, test 1 and Subject 17, test 2, the number of responses emitted on the light-correlated lever was about 2 to 8 times that emitted on the tone-correlated lever. This preference for the light-correlated lever occurred regardless of whether frequency of response maintained by the tone was less than, equal to, or greater than the frequency maintained by the light. Typically, those responses that were emitted on the tone-correlated lever occurred first; the rat then switched to the light-correlated lever and remained there for the duration of the interval.

The pattern of responding during compounding resembled that shown in the first ex-

Table 2

Mean number of responses emitted during each of the two test sessions on the levers correlated with light or tone is shown in columns 3 and 4. Mean number of responses emitted on the inappropriate lever in the presence of each S^D is shown in columns 5 and 6. Mean number of responses emitted on each lever during compounding is shown in columns 7 and 8 and total compound responses is shown in column 9.

Subject	Test	Single S^D s				Compound		
		Light-Correl. Lever	Tone-Correl. Lever	Responses on Tone-Correlated Lever in Presence of the Light	Responses on Light-Correlated Lever in Presence of the Tone	Light-Correlated Lever	Tone-Correlated Lever	Total
	column →	3	4	5	6	7	8	9
13	1	30.9	32.4	4.1	1.7	19.3	9.8	29.1
	2	23.9	27.1	2.8	1.6	18.0	8.0	26.0
14	1	17.7	17.6	1.5	1.5	12.2	10.7	22.9
	2	13.2	19.4	0.3	4.7	20.0	2.7	22.7
15	1	19.6	16.9	1.0	1.4	16.7	6.2	22.9
	2	13.6	13.3	1.4	1.2	16.8	3.5	20.3
16	1	21.9	19.0	1.1	2.7	21.7	7.7	29.4
	2	20.0	27.3	0.7	0.0	29.2	4.0	33.2
17	1	22.7	21.1	2.2	2.5	20.2	2.5	22.7
	2	19.4	25.5	4.8	0.0	12.7	11.6	24.3
18	1	30.9	23.0	0.7	4.1	27.0	6.5	33.5
	2	24.9	36.6	4.3	3.1	26.0	6.7	32.7

Fig. 2. Mean number of responses emitted during presentations of the single and compound S^D s by Subjects 13 to 18 for the two test days combined. Each S^D was correlated with its own lever and both levers were always extended. That portion of compound responses emitted on the light- and tone-correlated levers is indicated by the dotted lines within the bar graph denoting compound responding.

periment, when compounding occurred in the presence of the light-correlated lever and when both S^D s occurred in the presence of the same lever (compare columns 3 and 4 with column 9). Response frequency during compounding was greater than that to the single stimuli for five of the six animals over both days (Subjects 14 to 18, although this difference was nil for Subject 17). Overall, significantly more responses ($F(2,10) = 7.9$, $p < 0.01$) were emitted during compounding than during single S^D presentations. Frequency of response during compounding was significantly greater than response frequency to both tone and light ($p < 0.05$ and < 0.01 , respectively), indicating that summation did occur.

DISCUSSION

The first two experiments suggest a marked preference for the light-correlated lever during compounding, and that presence or absence of the light-correlated lever determined whether or not response summation would occur. Compounding light and tone in the presence of both levers produced summation, with nearly all of the responses emitted on the light-correlated lever. When compounding occurred in the presence of the light-correlated lever in the first experiment, summation also occurred.

However, when compounding occurred in the presence of only the tone-correlated lever, summation did not occur. Thus, not allowing subjects to respond on the preferred light lever during compounding prevented summation. During compounding in the presence of only a single lever, where each S^D is correlated with the same lever, the preferred light-correlated lever is, of course, always present. However, how light and its correlated lever came to exert these particular effects remains unexplained.

One explanation is that light was a more salient S^D than was tone. That is, the change from the S^A condition of darkness and no sound to light and no sound (light S^D) was much more salient and discriminable than the transition from S^A to no light and sound (tone S^D). During compounding, since light was more salient than tone, light could control a strong preference for responding on the light-correlated lever. Depending upon the presence or absence of that lever, summation would or would not occur. Suggestive evidence supporting this hypothesis comes from studies in which visual and auditory stimuli are combined and established as an S^D compound. The components are then presented separately to assess the control over responding exerted by each. Birkimer (1969) found that a houselight exerted substantially more control over responding than did white noise; far fewer responses were emitted during noise presentations than during light presentations. Thompson and Van Hoesen (1967) conditioned rats to avoid a compound stimulus of light and tone and then extinguished the behavior of the rats to one of the components of the compound. Intensity of the light or tone was either high or low. Subjects took considerably longer to extinguish to the high-intensity (more salient) component, regardless of whether it was light or tone.

To reduce this possible saliency of light over tone found in the present study, a third experiment was conducted. The houselight remained on during the entire session. The ensuing transition from S^A (light and no sound) to light S^D (light and no sound) should not be nearly so much more prepotent or discriminable than the transition from S^A to tone S^D . Compounding in the presence of either the light- or tone-correlated lever should produce similar results.

EXPERIMENT III: MANIPULATION OF BACKGROUND LIGHT INTENSITY METHOD

Ten different rats (Subjects 19 to 28) were run with the identical training and testing procedure followed with the two-lever chamber in the first experiment. For Subjects 19 to 21 and 27 to 28, the left lever was associated with light and the right lever with tone. This association was reversed with Subjects 22 to 23 and 24 to 26. With Subjects 19 to 23, a low-intensity houselight of 5.8 cd/m² (1.7 ft candles) remained on throughout each session. For Subjects 24 to 28, a medium-intensity houselight of 26.7 cd/m² (7.8 ft candles) was used. Each houselight was located by the front upper lefthand corner of the box. Intensity was measured at the lever. Intensity of the light S^D remained at 61.6 cd/m². Following the two days of compound tests, houselight intensity was increased for all subjects to 46.6 cd/m² (13.6 ft candles). Subjects were run for 15 more days, followed by two more days of compound tests.

RESULTS

Individual results are presented in Table 3 and group data are illustrated in Figure 3. In all instances except two (Subject 24 with the moderate-intensity houselight and Subject 20 with the high-intensity houselight), compounding S^D s while subjects responded on the light-correlated lever produced an increase in responding compared to light presentations (compare columns 5 and 6 of Table 3; see column 7 and Figure 3). This result is consistent with the result found in the first experiment when compounding occurred in the presence of the light-correlated lever.

Considering responding in the presence of the tone-correlated lever, the pattern of responding with the low-intensity houselight was somewhat similar to that found in the first experiment, where no houselight was ever on (compare columns 2 and 3; see column 4). Two rats (Subjects 20 and 23) showed a small per cent increase in responding during compounding, Subject 22 exhibited a moderate increase, while Subjects 19 and 21 showed a medium decrease in responding. The interaction between which lever was present during compounding and responding in the pres-

Table 3

Mean number of responses emitted during each test session by each subject on the levers correlated with tone or with light and to the compound formed by presenting the S^D correlated with the other lever is shown as a function of houselight intensity.

		Tone-Correlated Lever Present			Light-Correlated Lever Present		
Subject		Tone	Compound	Per Cent Change	Light	Compound	Per Cent Change
column →		2	3	4	5	6	7
Low-Intensity Houselight	19	8.3	6.7	- 19.3	14.1	32.7	+131.9
	20	18.0	20.0	+ 11.1	18.5	26.0	+ 40.5
	21	11.4	9.3	- 18.4	7.4	8.2	+ 10.8
	22	7.7	9.0	+ 16.9	5.7	14.5	+154.4
	23	19.2	21.8	+ 13.5	9.9	17.5	+ 76.8
Medium-Intensity Houselight	24	16.1	18.0	+ 11.8	25.8	23.0	- 10.9
	25	11.1	15.8	+ 42.3	26.0	40.0	+ 53.8
	26	8.6	14.0	+ 62.8	8.1	14.0	+ 72.8
	27	31.1	30.3	- 2.6	18.3	26.3	+ 43.7
	28	8.4	16.5	+ 96.4	11.9	20.2	+ 69.7
High-Intensity Houselight	19	15.1	24.8	+ 64.2	5.1	8.8	+ 72.5
	20	8.6	11.0	+ 27.9	16.1	13.5	- 16.1
	21	24.4	33.3	+ 36.5	15.5	19.0	+ 22.6
	22	5.2	12.3	+136.5	7.6	11.5	+ 51.3
	23	22.2	23.2	+ 4.5	23.3	23.5	+ 0.9
	24	24.5	27.2	+ 11.0	10.3	11.7	+ 13.6
	25	35.5	56.2	+ 84.5	11.8	24.5	+107.6
	26	12.8	16.2	+ 26.6	13.9	16.0	+ 15.1
	27	18.4	19.7	+ 7.1	19.2	24.8	+ 29.2
	28	9.9	18.5	+ 86.9	7.7	19.5	+153.2

ence of the single and compound S^Ds was significant at $p = 0.064$ ($F(1,4) = 7.16$) (see panel a of Figure 3). It would thus appear that houselight intensity was too low, relative to S^D light intensity, to do more than only slightly reduce saliency of the light S^D when subjects responded on the tone-correlated lever.

With the medium- and high-intensity houselights, however, compounding in the presence of the tone-correlated lever produced a notice-

able rise in response frequency for the majority of animals (compare columns 2 and 3; see column 4 and panels b and c of Figure 3). With the medium-intensity houselight, four of the animals (Subjects 24 to 26 and 28) emitted more responses during compound presentations than during tone presentations. This increase was small with Subject 24 but large with Subjects 25, 26, and 28. Subject 27 showed a small decrease in responding. With the high-intensity houselight, all 10 rats emitted more responses during compound presentations. This increase was small for Subjects 23, 24, and 27, moderate with Subjects 20 and 26, and large for Subjects 19, 21, 22, 25, and 28. The interaction between which lever was present during compounding and responding in the presence of the single and compound S^Ds was significant at only $p > 0.25$ ($F(1,4) = 1.07$) for the medium-intensity condition and $p = 0.096$ ($F(1,4) = 3.35$) for the high-intensity condition.

Fig. 3. Mean number of responses emitted during presentations of the single and compound S^Ds on the levers correlated with tone or light, as a function of houselight intensity. Each point is based on the combined data of all animals trained with that particular houselight intensity.

DISCUSSION

As houselight intensity increased from zero (Experiment 1) to high, compounding S^Ds

while subjects responded on the tone-correlated lever produced a larger and larger increase in responding compared to tone presentations. This can also be seen in Figure 4, where the mean per cent change in response frequency to the compound as compared to the single S^D is presented as a function of houselight intensity. The data from the first experiment, in which no houselight was present, are also included. Each data point is based on the mean of the per cent increase or decrease during compounding for all subjects in a particular houselight intensity condition. For subjects responding on the tone-correlated lever, there is an increase in responding during compounding compared to tone presentations as houselight intensity is increased. At the medium- and high-intensity levels, the difference between single and compound S^D s is about the same, regardless of whether compounding occurred in the presence of the tone-correlated lever or the light-correlated lever. It should also be noted that increasing houselight intensity did not reduce the difference in responding between single and compound S^D s when subjects responded on the light-correlated lever. Except for compound responding with the low-intensity houselight, the differences between light and the com-

pound were very similar at the other three intensity levels. Houselight intensity operated to make the tone a more salient S^D , rather than to reduce the saliency of the light.

Which S^D , if any, will become salient is probably influenced by several factors. Intensity-saliency of the S^D has already been shown to be an important variable. Species of subject may also be important. Certain stimuli may be naturally prepotent with certain organisms. Jane, Masterton, and Diamond (1965) trained cats to avoid shock using a compound stimulus consisting of a soft low tone and bright flashing light. Sound was found to be prepotent over light in controlling avoidance responses when the component stimuli were presented separately. This result is opposite to that found by Thompson and Van Hoesen (1967) using rats, where a high-intensity light was found to be prepotent over a low-intensity tone. Blough (1969) reported that auditory control was not as complete as visual control with pigeons; and Van Houten, Seraganian, and Rudolph (1972) noted that pigeons' behavior is controlled primarily by visual stimuli.

EXPERIMENT IV: DIFFERENT REINFORCEMENT SCHEDULES CORRELATED WITH EACH S^D AND LEVER

The third experiment demonstrated that control over behavior exerted by the light S^D and its correlated lever in the first two experiments could be manipulated by changing background light intensity. The fourth experiment sought to manipulate light's control over responding under the conditions of the first experiment; that is, with no houselight present. In the first experiment, light and tone were correlated with the same reinforcement schedule (FI 30-sec). In the fourth experiment, light and tone were correlated either with a schedule that reinforced nearly immediate and rapid responding upon onset of that S^D (FI 4.7-sec); or, with a schedule that did not reinforce as immediate or rapid responding as FI 4.7-sec upon onset of its S^D (FI 30-sec). It was believed that the very different contingencies of these schedules might be prepotent rather than the modalities of the S^D s correlated with the schedule. If so, the compounds should maintain similar levels of responding, regardless of whether compounding occurred in the presence of the light- or tone-correlated levers.

Fig. 4. Mean per cent increase or decrease in responding during compounding *vs* single- S^D presentations as a function of which lever was present during compounding and houselight intensity. Each point is derived from the combined data of all animals maintained under that particular intensity.

METHOD

Eight different rats (Subjects 29 to 36) were run with the identical training and testing procedure used with the two-lever box in the first experiment. For Subjects 29 and 30, and 35 and 36, the left lever was associated with light and the right lever with tone. For Subjects 31 to 34, this association was reversed. For Subjects 29 to 32, tone was correlated with FI 4.7-sec and light with FI 30-sec. This correlation was reversed for Subjects 33 to 36. Each schedule, its correlated S^D, and lever were presented on alternate days. Sessions with FI 30-sec lasted 1 hr. The subsequent session with FI 4.7-sec lasted until the animal collected about the same number of reinforcements as it had collected on the previous day with FI 30-sec.

Compound tests took place after 30 days of training. During compounding, the S^D correlated with the other schedule and lever was presented during periods of FI when subjects normally responded in the presence of the other S^D and its correlated lever and schedule. For Subjects 29 and 30, and 33 and 34, compounding occurred while subjects responded on the lever correlated with FI 30-sec on test day 1, and while they responded on the lever correlated with FI 4.7-sec on test day 2. This order was reversed for Subjects 31 and 32, and 35 and 36. Compounding occurred six times while subjects responded on the lever correlated with FI 30-sec and eight times while they responded on the lever correlated with FI 4.7-sec. When compounding occurred during the test session in which subjects responded on the lever correlated with FI 30-sec, the stimulus correlated with FI 4.7-sec remained on for as long as the S^D correlated with FI 30-sec did. Likewise, when compounding occurred while subjects responded on the lever correlated with FI 4.7-sec, the S^D correlated with FI 30-sec remained on for as long as the S^D correlated with FI 4.7-sec did.

RESULTS

For reasons to be explained shortly, both frequency and rate of response were measured. Therefore, only those responses emitted within 4.7 or 30 sec were counted. Latency of response, that is, time between onset of the S^D and the first response, was also measured with each schedule.

Individual data are presented in Table 4 and the group data are illustrated in Figure 5. Analysis of variance revealed that the reinforcement schedule associated with the S^D added to form the compound significantly changed ($F(1,6) = 81.9$, $p < 0.01$) the level of responding during compounding. Compounding S^Ds while subjects responded on the lever correlated with FI 4.7-sec reduced frequency of responding for all subjects (compare columns 2 and 3 of Table 4; see column 4). The per cent decline in responding was small for Subject 35, moderate for Subjects 29, 30, 33, and 36, and large for Subjects 31, 32, and 34. This reduction, however, was not significant ($p = 0.15$), probably because response frequency during single S^D presentations was already so low, due to the brevity of the FI 4.7-sec schedule. The compound could not reduce responding very much more. If response frequency is converted to response rate (see Panel A of Figure 5 and columns 2a and 3a), which is more independent of schedule duration than is frequency, rate of responding during compounding is significantly less ($F(1,7) = 17.1$, $p < 0.01$) than during single S^D presentations.

When the S^Ds were combined while subjects responded on the lever correlated with FI 30-sec, both frequency and rate of response increased significantly ($p < 0.01$), compared to single S^D presentations, for all subjects (see panel B; compare columns 5 and 6 and 5a and 6a; see column 7). Per cent increase in frequency during compounding was moderate for Subjects 30, 33, and 34 and large for Subjects 29, 31, 32, 35, and 36.

No significant effect ($F(1,6) < 1.0$, $p > 0.25$) due to modality of the S^D was found. Combining S^Ds while subjects responded on the lever correlated with FI 4.7-sec reduced responding in all cases, regardless of whether light or tone was correlated with FI 30-sec. Combining S^Ds while subjects responded on the lever correlated with FI 30-sec increased level of responding in all instances, regardless of the modality of the S^D correlated with FI 4.7-sec.

Considering the latency data, when the S^Ds were combined while subjects responded on the lever correlated with FI 4.7-sec, a significant effect ($F(1,6) = 6.2$, $p < 0.05$) due to the modality of the S^D was found. Presenting light while subjects responded on the FI 4.7-sec

Table 4

Mean number of responses emitted during each test session by each subject on each lever during presentations of single and compound S^ps, as a function of reinforcement schedule and modality of S^p associated with each lever, is shown in columns 2-7. Frequency of response, converted to rate of response, is shown in parentheses in columns (2a)-(6a). Mean latency of response is shown in the right half of the table (columns 8-11). The schedule of reinforcement associated with a particular single S^p is indicated in parentheses.

Subject	FREQUENCY AND RATE (in parentheses) OF RESPONSE							LATENCY OF RESPONSE			
	Tone S ^p & Lever			Light S ^p & Lever			Per Cent Change	Tone S ^p & Lever		Light S ^p & Lever	
	Present (FI 4.7-sec)	Compound	3 (3a)	4	5 (5a)	6 (6a)		Present (FI 4.7-sec)	Comp	Present (FI 30-sec)	Comp
column →	2 (2a)						7	8	9	10	11
29	2.4(0.51)	1.8(0.38)		-25.0	15.0(0.50)	25.9(0.86)	+ 72.7	2.7	3.4	17.5	6.3
30	6.8(1.45)	4.5(0.96)		-33.8	26.9(0.90)	32.5(1.08)	+ 20.8	1.3	1.8	4.4	2.8
31	3.5(0.74)	1.5(0.32)		-57.1	23.5(0.78)	47.7(1.59)	+102.9	3.0	5.4	15.4	3.5
32	5.6(1.19)	3.2(0.68)		-42.8	10.7(0.36)	23.5(0.78)	+119.6	1.4	2.9	11.8	2.2
<hr/>											
Tone S ^p & Lever											
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Light S ^p & Lever											
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33	4.8(1.02)	4.0(0.85)		-16.6	21.8(0.73)	27.8(0.93)	+ 27.5	2.5	1.8	13.3	6.8
34	2.1(0.45)	0.7(0.15)		-66.7	23.9(0.80)	29.3(0.98)	+ 22.5	3.4	4.3	8.8	2.9
35	1.0(0.21)	0.9(0.19)		-10.0	12.2(0.41)	24.3(0.81)	+ 99.1	4.0	3.7	12.9	5.9
36	2.5(0.53)	1.8(0.38)		-24.0	15.4(0.51)	25.8(0.86)	+ 67.5	4.5	3.6	14.8	7.1
column →	2 (2a)	3 (3a)	4	5 (5a)	6 (6a)	7		8	9	10	11

Fig. 5. Mean rate (sec) (panels A and B) and mean latency (sec) (panels C and D) of response for Subjects 29 to 36 combined, during single and compound S^D presentations, as a function of reinforcement schedule correlated with each S^D and which lever was present. The S^D correlated with the lever that was present was correlated with either FI 4.7-sec (panels A and C) or with FI 30-sec (panels B and D). Therefore, the S^D added to form the compound was correlated with FI 30-sec in panels A and C and with FI 4.7-sec in panels B and D.

tone-correlated lever produced a significant increase ($p < 0.05$) in latency. However, presenting tone while subjects responded on the FI 4.7-sec light-correlated lever did not significantly change ($p > 0.25$) latency (see panel C; compare columns 8 and 9). When subjects responded on the lever correlated with FI 30-sec, latency was significantly reduced ($F(1,6) = 40.6$, $p < 0.01$) compared to single S^D presentations. This was true regardless of whether light or tone was correlated with FI 4.7-sec (see panel D; compare columns 10 and 11).

DISCUSSION

These results show that the very different reinforcement contingencies associated with each S^D , rather than the modality of the S^D , affected frequency and rate of responding during compounding. Presenting either light or tone correlated with FI 30-sec while subjects responded on the lever correlated with FI 4.7-sec significantly reduced response rate. Combining either tone or light correlated with FI 4.7-sec with the S^D that maintained responding on the FI 30-sec correlated lever signifi-

cantly increased frequency and rate of response. It would seem that the preference for and control over responding exerted by light and its correlated lever, which was found in the earlier experiments, occurred when the reinforcement schedules correlated with light and tone were very similar. When each schedule controlled a different pattern of responding, the modality of the S^D seemed not differentially to affect responding during compounding.

The latency data show that presenting the S^D correlated with FI 4.7-sec, while subjects responded in the presence of the S^D correlated with FI 30-sec, significantly reduced latency. This was true regardless of whether tone or light was correlated with FI 4.7-sec. These data are in good agreement with the response frequency and rate data, indicating that the effect of the FI 4.7-sec correlated S^D was to cause the subject to begin responding much sooner than with just the FI 30-sec correlated S^D present.

The latency and frequency and rate data are not in as good agreement when the S^D cor-

related with FI 30-sec was presented while subjects responded in the presence of the S^D correlated with FI 4.7-sec. When the FI 4.7-sec correlated S^D was tone, latency during compounding increased significantly. This result is consistent with the drop in frequency and rate. However, when the FI 4.7-sec correlated S^D was light, latency during compounding showed no significant change. This does not reflect the decline in frequency and rate. Frequency of response fell for all four animals during compounding, but latency decreased slightly with Subjects 33, 35, and 36 and increased only with Subject 34. It is not clear, however, that these results are due entirely to the modality of the S^D, or whether the results reflect a weakness of the latency measure. The very small reduction in latency for the three animals (0.7, 0.3, and 0.9 sec for Subjects 33, 35, and 36, respectively) might simply not be indicative of how many times the subject was going to lever press in 4.7 sec. Subjects responded just slightly sooner but also less often. Where the interstimulus interval between onset of S^D and availability of reinforcement is brief, latency and frequency may not always correlate very highly. It is well established, for example, in classical conditioning, where the interstimulus interval between CS and UCS is brief, that latency and frequency of the CR are not positively correlated (Hall, 1966, p. 147).

The results of the fourth experiment again point out the very different effects obtained during compounding when each S^D is correlated with its own response lever. An S^D correlated with a short-latency and high-rate-of-response reinforcement schedule (FI 4.7-sec) was presented while subjects responded in the presence of an S^D correlated with a longer-latency and slower-rate-of-response schedule (FI 30-sec). Response rate and frequency increased during compounding. When the opposite conditions prevailed during compounding, rate and frequency decreased. If each of these schedules and their S^D were correlated with the same single response lever, only one of these results could occur. Miller and Price (*in press*) conducted such an experiment in conjunction with another study and found that responding increased significantly during compounding.

In conclusion, light and tone S^Ds were correlated with their own response lever and the

S^Ds were compounded while subjects responded on each lever. The compound was shown to affect responding depending upon which lever and S^D were present during single S^D presentations, absence or presence and intensity of background stimulation from the same modality as one of the S^Ds, and the reinforcement schedule associated with each S^D. The two-lever method, then, provides a more complete description of the effects of combining S^Ds than does the traditional single-lever method.

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