

*CONTROL OF RESPONDING BY THE ELEMENTS OF A
COMPOUND DISCRIMINATIVE STIMULUS AND
BY THE ELEMENTS AS INDIVIDUAL
DISCRIMINATIVE STIMULI¹*

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In the first of two studies, the responding of four albino rats was differentially reinforced in the presence of noise and light together and then tested in the presence of the noise and the light separately during extinction. The light exercised substantially more control of responding than did the noise. In the second study the responding of a similar group of four rats was differentially reinforced in the presence of the noise and the light separately. Control of responding by the light developed more rapidly than control by the noise. Results suggest that levels of control by stimuli after differential reinforcement with respect to the stimuli together can be predicted by the rates of development of control during differential reinforcement with respect to the stimuli separately.

When two independent stimuli are combined in a compound stimulus and used as the stimulus correlated with reinforcement (S^D) in a differential training procedure, the levels of control attained by each of the stimuli in the compound are not easily specified. Pavlov (1927) studied such stimulus compounds in the classical conditioning situation and concluded that the relative intensities of the elements determined the degree of control exerted by each. Vatsuro (in Berlyne, 1960) examined the same problem in an instrumental situation and obtained the same result, but used only one subject. Reynolds (1961) performed a similar study with two pigeons. During extinction, one of his subjects responded primarily to the first element, the second subject to the second element. An intensity analysis does not predict Reynolds' results nor is the reliability of control by a particular element across subjects established.

A recent study by Johnson and Cumming (1968) examined control of responding by the elements of a compound visual S^D . After differential reinforcement of responses to hue 1 and vertical line (S^D) versus hue 2 and horizontal line (S^A), pigeons showed reliably

greater control by hue 1 than by vertical line. Differential reinforcement of responding to a single element of a compound S^D before or after compound S^D training increased the control exerted by that element, and reducing the intensity of the single element during prior single-element training led to less control by that element following the compound S^D differential training. Thus, a particular element of a compound S^D can control responding reliably across subjects, and the degree of control exerted by an element is increased by differential training with it.

The preceding studies shared a concern with the development of stimulus control by the elements of a compound S^D , control being identified by the ability of individual elements to raise responding above S^A levels. Other studies have also examined stimulus control by the elements of a compound stimulus, but have defined control in terms of the steepness of generalization gradients obtained by varying one or more elements of the compound.

Butter (1963) and Fink and Patton (1953) reinforced responding in the presence of a compound stimulus without presenting a stimulus not correlated with reinforcement (S^A), a technique referred to as single-stimulus training, then demonstrated a greater reduction in responding to changes in more than one element of the compound stimulus. Their results indicated that more than one dimension of a compound stimulus can gain control over responding.

¹This research was supported by grant number 66-7 from the Arts and Sciences Research Committee, University of Louisville. Mr. Gary Bodner assisted in running the subjects. Reprints may be obtained from John C. Birkimer, Dept. of Psychology, University of Louisville, Louisville, Kentucky 40208.

In a recent series of papers, Newman and Baron (1965), Freeman and Thomas (1967), and Newman and Benefield (1968) presented evidence suggesting that: the hue dimension develops control over pigeons' responding more easily than does an angularity dimension when a hue and vertical line are exposed on a key during single-stimulus training, that the presence of the training hue during generalization testing reduces the steepness of obtained gradients of responding to angularity of the line, and that differential training to line presence (S^D) versus absence (S^Δ) increases the control by angularity when training hue is present during generalization testing. In one part of the Newman and Baron study, a group of pigeons given differential training to hue 1 (S^D) versus hue 2 (S^Δ) with vertical line always present, showed more rapid development of stimulus control than a group trained to vertical line present (S^D) versus absent (S^Δ) with hue 1 always present. Either the presence of irrelevant hue hindered development of stimulus control by the line or control by hue developed more rapidly than control by line during differential training. Combining this latter possibility with Johnson and Cumming's finding (that hue controls more responding than does vertical line after compound S^D differential training) suggests the possibility that those stimuli more easily developing control during individual S^D differential training will also exert greater control after compound S^D differential training.

The present study examined the possibility of a positive relationship between relative levels of control over responding by stimuli after differential training together as a compound S^D and relative levels of control of responding by each stimulus during individual S^D differential training. Pursuing the suggestions of Pavlov and Vatsuro, a low-intensity white noise and a relatively high-intensity light were combined as a stimulus compound and a group of rats was given differential training to the compound. Extinction testing to each of the two components separately permitted assessment of the relative control over responding exerted by each. A second group of subjects was then given differential training to each of the two stimuli to determine the levels of control attainable by each stimulus under this latter procedure.

METHOD

Subjects and Apparatus

A total of eight male Sprague-Dawley rats, approximately 100 days old, four rats in each of the two studies, were trained 1 hr per day in a commercial operant conditioning apparatus (Lehigh Valley 1316). A white noise of 63-db intensity (re. 0.0002 dynes/cm²), 4 db above the 59-db ambient sound level in the apparatus, and the houselight in the chamber were used as stimuli. The reinforcer for the bar-pressing response was 0.01 cc of 40% sucrose solution, and subjects were maintained on 12 g of lab chow per day. Electromechanical equipment controlled events in the chamber and recording.

EXPERIMENT 1

Procedure

Four subjects received three days of magazine training during which free deliveries of sucrose were separated by a mean interval of 60 sec. After one day of shaping, subjects received three days of continuous reinforcement (CRF) training. Thirteen days of discrimination training then began, with the compound S^D (noise and houselight) presented for 20-sec periods. Presentations of the compound S^D occurred independently of the subjects' behavior and were separated by S^Δ periods, with a mean duration of 20 sec, during which both noise and light were absent. For six days, CRF was in effect during the compound S^D , then two days of FR 3 (one reinforcement for every third response) in S^D and, finally, five days of FR 10 in S^D were scheduled. Ratios partially completed during one S^D carried over to the next.

On the day after the thirteenth discrimination training day, extinction testing was performed. Noise and light were presented individually for 20-sec periods with S^Δ periods separating each stimulus presentation. The order of presentation of noise and light was counterbalanced and the S^Δ periods had the same mean duration (20 sec) as used during training. Responses to each stimulus and to the S^Δ periods were recorded and testing continued for 12 ABBA sequences or until subjects had made no responses for two sequences. Two rats began the testing sequence with noise and two with light.

RESULTS

Subjects easily learned the discrimination; by the last day of training each of the animals showed a discrimination ratio of S^A response rate to S^D response rate equal to or less than 0.05.

Table 1

Number of extinction responses to light, to noise, and one-half the responses to S^A, for each subject in Exp. 1.

Subject	Stimulus Condition		
	Light	Noise	S ^A /2
1	154	50	10
2	63	22	8.5
3	111	11	4
4	132	2	4.5

Table 1 shows the number of extinction test responses made by each subject to light and to noise and one-half of responses to S^A. Since each stimulus was presented only half as often as S^A during extinction testing, halving the S^A responses permits comparison of number of responses across stimulus conditions with time in each condition equated. For each subject, the noise obviously controlled responding to a much lesser extent than did light; responding to noise represented, for Rats 1 through 4, respectively, 32%, 35%, 10%, and 2% of responding to light.

DISCUSSION

Results of Exp. 1 indicated that a low-intensity noise acquires substantially less control over responding than does a relatively high-intensity light when responses are differentially reinforced to the two stimuli together as a compound S^D. Johnson and Cumming's finding that one element of a compound S^D can primarily control responding, reliably across subjects, is extended to the present subject, the rat, and to stimulus compounds involving elements which act on different sensory modalities.

Since Exp. 1 demonstrated greater control of responding by light than by noise, Exp. 2 was performed to assess the development of stimulus control by each stimulus during differential training to each stimulus singly.

EXPERIMENT 2

Procedure

In the second study, four other rats received two days of magazine training, one day of shaping, and two days of CRF. Discrimination training was then begun with noise or light presented, in random order, until the subject had produced five reinforcements on the CRF schedule. Stimuli, either noise or light, were again presented independently of the subjects' behavior with a mean S^A duration of 20 sec separating each stimulus period. After four days of this training, FR 3 during S^D was scheduled for two days, and then three days of FR8 in S^D. Beginning on the last day of FR 8, S^D durations were limited to 20 sec regardless of the number of reinforcements produced. During this procedure, ratios partially completed during one S^D carried over to the next S^D period. Recording of discrimination performance began on this day. FR 15 was then scheduled during S^D for the remainder of the study. S^A response rates began to rise under this procedure, so on the fourth (Rats 1 and 2) and on the sixth (Rats 3 and 4) day of FR 15, a delay contingency was added to S^A such that an S^D presentation could not begin, even if scheduled, until no responses had occurred for 10 sec. Responses to each stimulus and to the S^A periods were recorded, as were the number of presentations of each stimulus.

Figure 1 and Table 2 indicate S^A/S^D discrimination ratios for Rats 1 through 4 over all days on which discrimination performance was recorded. Performance deteriorated over the first two or three days of observation and was due to proportionally greater increases in S^A response rates (see Table 2) with the increased FR requirement (FR 15) on Day 2. This increased S^A rate suggests that responding was not yet under good control of the two S^Ds.

Over the first several days, superior control by light was indicated by lower discrimination ratios to that S^D; Rats 1 through 4 showed, respectively, lower ratios to light on 6, 4, 4, and 5 of the first six days and, in many cases, these ratios were substantially lower than those to noise. As control by the S^Ds improved, and discrimination ratios dropped, the ratios to noise and to light became equal or nearly so, making it difficult to detect any superiority in

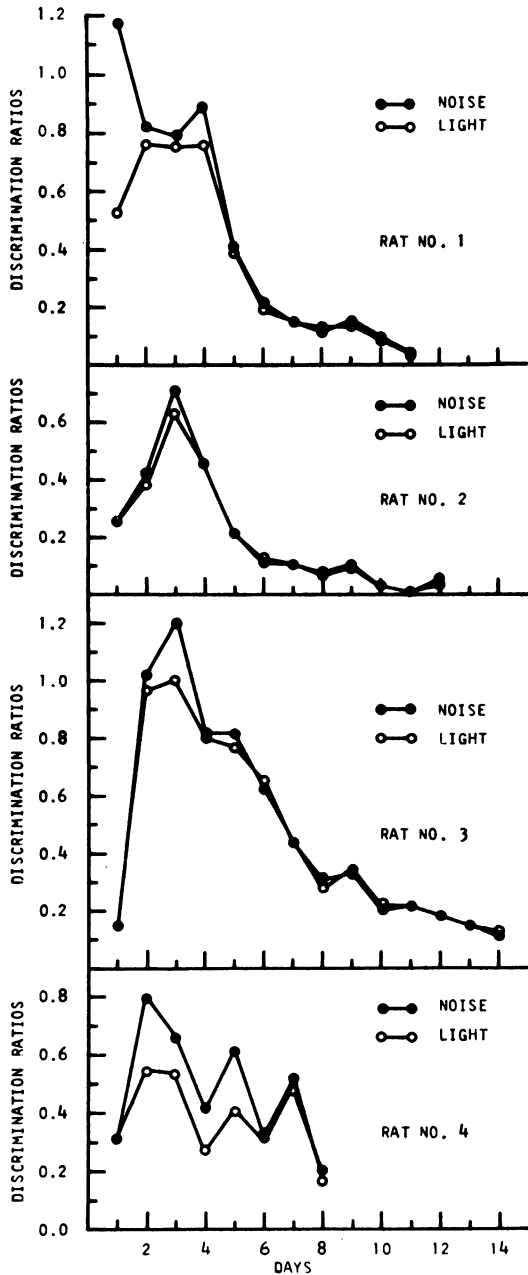


Fig. 1. Discrimination ratios (responses during S^A /responses during S^D) to noise and to light over days for each of the four subjects in Exp. 2.

control by light (Rat 4 was discontinued after Day 8 because of procedural irregularities.)

DISCUSSION

Experiment 2 indicated that during the development of stimulus control by light and

noise, with each individually serving as an S^D , light acquired control more quickly than noise, discrimination ratios being lower to light over the first several days of observation. As each stimulus developed control over the response, however, superiority in control by light diminished, with each stimulus finally controlling about equally well.

GENERAL DISCUSSION

The results of the two studies indicate that: (1) a relatively high-intensity light develops much more control over responding than does a low-intensity white noise when the two stimuli are combined as a compound S^D during differential training, and (2) when each is individually used as an S^D , the light develops control over responding more quickly than the noise, with the two stimuli finally controlling responding about equally well.

If the present results extend to other pairs of stimuli, it would be possible to predict which of two stimuli will exert greater control after compound S^D differential training from information about the rate at which each develops control during individual S^D differential training.

The present results were obtained with stimuli differing both qualitatively and quantitatively, and are thus predictable from the phenomenon of stimulus intensity dynamism (Hull, 1951), recently reviewed by Gray (1965). Accordingly, the finding that light develops control over responding more quickly than noise indicates that it is relatively more intense than noise. During compound S^D differential training, the stimuli develop greater reaction potential the greater their intensities: thus, light develops greater control than noise. This explanation does not apply to stimuli differing only qualitatively, but results reported by Farthing and Hearst (1968), after the present work was completed, indicate that the relationship found in the present study holds for such stimuli. Giving one group of pigeons differential training to a vertical (S^D) versus horizontal (S^A) line and a second group training to blue (S^D) versus green (S^A) hue on a key, they found great differences in the rate of development of stimulus control, with hue superior to line. Another group of pigeons given differential training to vertical line and blue (S^D) versus horizontal line and green (S^A)

Table 2

Discrimination ratios (responses during S^A/responses during S^D) to noise and to light and S^A response rates (responses/min) for subjects in Exp. 2.

Days	Subject											
	1			2			3			4		
	Noise	Light	S ^A	Noise	Light	S ^A	Noise	Light	S ^A	Noise	Light	S ^A
1	1.17	0.53	12.2	0.25	0.25	10.3	0.15	0.15	3.7	0.30	0.30	7.6
2	0.82	0.76	51.1	0.42	0.38	15.0	1.02	0.97	27.7	0.81	0.55	14.1
3	0.79	0.75	41.9	0.72	0.63	30.3	1.21	1.10	75.6	0.66	0.54	13.4
4	0.90	0.76	64.5	0.46	0.45	20.8	0.82	0.80	65.0	0.41	0.27	4.8
5	0.41	0.39	28.1	0.22	0.21	9.9	0.82	0.77	84.2	0.61	0.41	11.1
6	0.21	0.19	16.8	0.11	0.12	5.1	0.63	0.65	65.2	0.32	0.30	6.1
7	0.15	0.15	12.4	0.11	0.11	5.1	0.44	0.44	50.4	0.52	0.49	12.6
8	0.12	0.13	10.8	0.08	0.07	3.0	0.31	0.28	29.0	0.18	0.19	4.5
9	0.16	0.14	13.8	0.11	0.10	4.0	0.33	0.35	41.4			
10	0.10	0.09	8.7	0.03	0.03	1.0	0.20	0.21	24.7			
11	0.05	0.04	3.7	0.01	0.01	0.5	0.22	0.22	25.6			
12				0.04	0.06	1.4	0.19	0.19	25.7			
13							0.15	0.15	17.7			
14							0.11	0.13	13.1			

showed, during extinction testing to each, greater control by the blue hue than by the vertical line.

Farthing and Hearst used separate groups of subjects to demonstrate much more rapid development of control by hue than by line; the present study used a single group of subjects to demonstrate somewhat more rapid development of control by light than by noise. Species, stimulus, or other procedural differences may account for the smaller difference in rate of development of control in the present study. Alternatively, Thomas, Noel, and Eck (1968) showed that prior differential training of pigeons to vertical *versus* horizontal line led to more rapid development of control during later differential training to hue, by speeding extinction to the S^A hue. Thus, prior differential training can facilitate the development of control by a new stimulus. Perhaps the development of control by light in the present study, in reducing S^A responding, speeded the development of control by noise. Such facilitation of the more difficult discrimination by the less difficult could not occur in the between-group design used by Farthing and Hearst.

In the present study, somewhat more rapid development of control by light than by noise was observed when each served as an S^D, but much greater control by light than by noise followed compound S^D differential training. In terms of Baron's (1965) notion of attend-

ing hierarchies, or Freeman and Thomas' (1967) notion of cue utilization, it appears that a stimulus somewhat more easily attended to during individual S^D differential training was attended to or utilized nearly to the exclusion of the other stimulus during compound S^D differential training.

REFERENCES

- Baron, M. R. The stimulus, stimulus control, and stimulus generalization. In D. I. Mostofsky (Ed.), *Stimulus generalization*. Stanford: Stanford University Press, 1965. Pp. 62-71.
- Berlyne, D. E. *Conflict, arousal, and curiosity*. New York: McGraw-Hill, 1960.
- Butter, C. M. Stimulus generalization along one and two dimensions in pigeons. *Journal of Experimental Psychology*, 1963, 65, 339-346.
- Farthing, W., and Hearst, E. Attention in the pigeon: two testing procedures. Paper presented at the meeting of the Psychonomic Society, St. Louis, October 1968.
- Fink, J. B. and Patton, R. M. Decrement of a learned drinking response accompanying changes in several stimulus characteristics. *Journal of Comparative and Physiological Psychology*, 1953, 46, 23-27.
- Freeman, F. and Thomas, D. R. Attention vs. cue utilization in generalization testing. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, May 1967.
- Gray, J. A. Stimulus intensity dynamism. *Psychological Bulletin*, 1965, 63, 180-196.
- Hull, C. L. *Essentials of behavior*. New Haven: Yale University Press, 1951.
- Johnson, D. F. and Cumming, W. W. Some determiners of attention. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 157-166.

- Newman, F. L. and Baron, M. R. Stimulus generalization along the dimension of angularity: a comparison of training procedures. *Journal of Comparative and Physiological Psychology*, 1965, **60**, 59-63.
- Newman, F. L. and Benefield, R. L. Stimulus control, cue utilization and attention: effects of discrimination training. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, May 1968.
- Pavlov, I. P. *Conditioned reflexes*. Trans. by G. V. Anrep. London: Oxford University Press, 1927.
- Reynolds, G. S. Attention in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 203-208.
- Thomas, D. R., Noel, R. C., and Eck, K. O. Selective attention vs. general attentiveness: II Effects of prior training on subsequent learning. Paper presented at the meeting of the Psychonomic Society, St. Louis, October 1968.

Received 2 May 1968.