CONTROL OF A CONTINUOUS RESPONSE DIMENSION BY A CONTINUOUS STIMULUS DIMENSION¹

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Pigeons were trained to respond to stimuli from a continuous stimulus dimension (tonal frequency) with response values from a continuous response dimension. Both the number of points of correspondence and problem difficulty were varied. After training, subjects were tested with stimulus values intermediate to those trained. During these test tones, subjects emitted only those response values reinforced during training. The study suggested that if there are fast and efficient methods to obtain control of a continuous response dimension by a continuous stimulus dimension, these methods must depend on factors other than simple generalization.

Many skilled forms of behavior observed in the natural environment require small differences in the response when small differences occur with respect to the stimuli. This phenomenon has been termed the continuous repertoire (Skinner, 1953; Holland and Skinner, 1961). An example of the formation of a continuous repertoire is found in young children learning to copy sample drawings. Lines on the sample serve as stimuli for the drawing movements the child must make. The extent to which the drawn lines can be discriminated as similar to the sample is the extent to which the child's lines can serve as reinforcing stimuli for appropriate copying movements. Within the limits of the discriminative ability of the child, these appropriate drawing movements are reinforced and the correspondence between variations in the response field and variations in the stimulus field are established. There are many examples of continuous repertoires in the natural environment such as

singing on key, handwriting, and a wide variety of motor behaviors.

Although continuous repertoires are important in everyday behavior, the process has seen little experimental analysis. An applied study (Holland and Matthews, 1963) showed that children with articulation difficulties who are trained to discriminate the speech sounds they misarticulate improve their sound production even before any formal training on production. What is still needed, however, is a careful experimental analysis of the factors leading to the formation of a continuous repertoire. What should be determined are the conditions that enable different points on a stimulus dimension to evoke slightly different values along a response dimension (*i.e.*, the conditions that produce response mapping).

While the differential reinforcement resulting from the differential feedback produced by the responses would seem to be an important factor, an experimentally simpler possibility is worthy of exploration. In typical stimulus generalization experiments, as the stimulus value is changed from the discriminative stimulus (S+) value, the response decreases in frequency. But in studies that measure stimulus generalization, a single key is used and the response is not free to vary in topography. The possibility remains that after training a few points along a stimulus dimension to differing response topographies along a response dimension

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sion, presentation of intermediate stimulus values might evoke intermediate response values. Indeed, Herrnstein and Van Sommers (1962) explored the possibility of obtaining psychophysical scaling with pigeons by training five interresponse times to five stimulus values and then testing with intermediate stimulus values. They found that a power function fit their data (*cf.*, Stevens and Galanter, 1957). Therefore, Herrnstein and Van Sommers seem to have established a continuous repertoire by simply training five separate positive stimuli ($S+s$) along a stimulus dimension to five separate interresponse times on the response dimension.

Not all investigators have obtained response mapping to intermediate stimuli. Cross and Lane (1962), Migler (1964), and Cumming and Eckerman (1965) used a stimulus dimension that varied in intensity and did not obtain intermediate responding. However, each of these studies trained only two points along the stimulus dimension. Migler, who reinforced different rates of switching between two keys in response to two click rates, reinforced as one of his points a 0-sec delay. Thus, switching as rapidly as possible was reinforced. Responding to the 0-sec delay may be qualitatively different than other delays in producing especially strong response stereotypy and in effect "anchoring" the response. This anchoring, in addition to the lack of training any intermediate points between the two extremes, may have prevented response mapping. Boakes (1969) did find some limited evidence of intermediate responding. Boakes, like Migler, used the time between successive responses on two response manipulanda (R-R time) but avoided the anchoring effect of training a 0-sec R-R time. He obtained intermediate responding to intermediate stimulus values when the shorter R-R time was paired with the brighter stimulus but not when it was paired with the dimmer stimulus. It is possible that more intense stimuli directly result in faster responding without benefit of training more than one R-R time. Thus, Boakes' results are somewhat equivocal as to whether response mapping may occur when two points are trained along a dimension.

Boakes also brought into question the results of the one study (Herrnstein and Van Sommers, 1962) that seemed to give clear evidence that response mapping occurred when

more than two points were trained. Boakes suggested that since averaged data were reported, the Herrnstein and Van Sommers findings might have resulted from subjects distributing their responses between the short and long R-R times that had been reinforced, rather than responding with intermediate R-R times to test stimuli. Therefore, the average of trained responses, rather than new responses, may account for the results.

Thus, in studies involving response mapping, the results have been inconclusive. Boakes' (1969) results suggest that intensity affects response latency or magnitude and that the anchoring of highly discriminable responses has a critical effect. The present study determined whether a continuous repertoire appears from the conditioning of a dimension in which stimulus intensity cannot account for the results. In addition, the data were not averaged. Moreover, points were chosen to avoid strong anchoring effects and three points were conditioned to determine the effect of the number of points trained.

METHOD

Subjects

Eight naive White-Carneau pigeons were maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

The apparatus was a modified Grason-Stadler experimental chamber. On one wall, a uniform gray response surface, 10 in. by 1 in. (25.4 by 2.54 cm), was located 8 in. (20 cm) above the floor and 2 in. (5 cm) from each side wall. The opaque gray response surface facing the subject consisted of a flexible piece of gray plastic covering a fine network of vertical wires. The number of vertical wires joined sequentially to a common electrical contact determined the extent of the response surface scored as a recording unit. Responses on any area of the response surface moved the wires under that area into electrical contact with a common electrode. This contact completed an electrical circuit, which was then amplified in order to drive relays, counters, *etc.* A more detailed description of the materials and circuitry employed for this touch-sensitive response surface is available elsewhere (Fitzhugh and Katsuki, 1971). The touch-sensitive re-

sponse surface required a minimum force of 0.196N to be operated and, for purposes of recording response variability, was divided into 10 areas of 1 in. (2.54 cm) each. These divisions were made electrically and were not perceptible to the subjects. Successive 1 in. (2.54 cm) areas from left to right were labelled areas 1a, 1b, 2a, 2b, 3a, 3b, 4a, 4b, 5a, and 5b for purposes of data analysis. To avoid recording multiple responses when a response was emitted to locations between two adjacent response areas, the first impulse from any area terminated the recording of responses for 75 msec. Illumination was provided by a diffuse 7-w houselight mounted in the center of the chamber's ceiling. A food magazine, 10 by 2 in. (25.4 by 5 cm), was located 10 cm below the response surface. The reinforcer consisted of a relay produced click followed 100 msec later by a 3.5 sec period of access to mixed grain presented by a grain hopper extending the length of the magazine. To prevent unauthorized access to grain when the hopper was not raised, the magazine had vertical wires at 0.4 in. (1

cm) intervals along its length. During the reinforcement cycle, the houselight was turned off and two diffuse 50-w bulbs directly above the grain were turned on.

A speaker was mounted 3 in. (7.6 cm) above the response surface along the centerline of this wall. The speaker could present pure tones of 1250 Hz, 1470 Hz, 1668 Hz, 2222 Hz, and 2500 Hz (tones one to five respectively) at 90 dB relative to 0.0002 dynes/cm sq. Figure 1 shows a schematic representation of the response surface and the tones appropriate for each area. The experimental chamber was housed in an air-conditioned room masked by white noise. Automatic equipment, housed in a separate room, controlled reinforcement contingencies, stimulus changes, and the recording of responses.

Procedures

Throughout the study, sessions terminated after 50 reinforcements. The reinforcement procedure was somewhat unusual in that both a primary and an explicit secondary reinforcer

Fig. 1. Schematic representation of the response surface with the locations of the discriminations for each group. Areas associated with reinforcement during a particular training tone are indicated by the arrows.

were employed. A relay produced click preceded the presentation of grain during the early training sessions to ensure that the click acquired secondary reinforcing properties. The explicit secondary reinforcer was employed to maintain responding to the novel stimuli during testing. Any reinforcement during testing causes problems to some degree. A number of studies (*e.g.*, Zeiler, 1965) have demonstrated that reinforcing responses to novel stimuli on tests with a primary reinforcer tends to bias further testing. Extinguishing responses on tests also can create problems. If no responses during any stimulus are reinforced, extinction of responding would occur. While an intermittent schedule of reinforcement during training prolongs extinction on tests, the discriminations trained in the present study were too complex to be readily amenable to low-density schedules of reinforcement. The present study attempted to avoid this dilemma by employing both intermittent primary reinforcement and continuous secondary reinforcement. During the last stage of training, the probability that each correct response would be followed by the presentation of food was reduced to 0.5. A correct response was always followed by the click. During the test sessions, the same schedule of primary and explicit secondary reinforcement was maintained for the training stimuli to prevent extinction. During each novel stimulus, however, any response was followed by the secondary reinforcer. Thus,

during testing, secondary reinforcement was provided nondifferentially for responses during novel stimuli.

All subjects in the present study had an identical history of 11 sessions of continuous reinforcement of responses on any area of the response surface and two sessions of extinction. Table 1 shows the training procedure used for each subject. During Sessions 1 and 2, there was continuous reinforcement of responses on any area. At the beginning of Session 3, a single tone was introduced for each subject. Trials were 30 sec in duration if no response occurred and were followed by a 6-sec inter-trial-interval with both the houselight and tone off. During Session 3, trial duration was reduced in 0.5-sec steps until each trial was 6 sec in duration. A response to any area terminated the trial and produced the intertrial interval. Responses to appropriate areas also produced the click and access to the reinforcement hopper for the first 3.5 sec of the inter-trial interval.

Discrimination training. Each of the groups learned a different set of discriminations. Figure 1 shows the discriminations for each group. Group 1-3-5 learned to discriminate tones appropriate to areas 1, 3, and 5. Group 2-4 learned to discriminate tones appropriate to areas 2 and 4. Group 1-5 learned to discriminate tones appropriate to areas 1 and 5. Since Group 1-5 had training with the most widely spaced stimuli, and also had the additional stimuli from the ends of the response

Table 1
Training Procedures

Procedure	Sessions		
	Group 1-5 Training Tones 1 and 5	Group 2-4 Training Tones 2 and 4	Group 1-3-5 Training Tones 1, 3, and 5
No tones. Reinforcement of each response to any area.	1-2	1-2	1-2
Only one training tone in each session.	3-12	3-12	3-16
Reinforcement of each response on an appropriate area.			
Discrimination training with training tones randomly alternated. Each response on an appropriate area reinforced.	13-40	13-72	17-76
Discrimination training as above except that the probability of primary reinforcement was reduced to 0.5.	41-60	73-92	77-96

surface, the discrimination should have been relatively easy for these subjects.

Discrimination training for Group 1-3-5 (S-114, S-116, S-124, and S-125) began with tone three during Sessions 3 and 4. During tone three, only responses to areas 3a and 3b were reinforced. During Sessions 5 to 7, only tone one was employed and responses to areas 1a and 1b were reinforced. During Sessions 8 to 10, tone five was present and responses to areas 5a and 5b were reinforced. In Sessions 11 to 13, tone three only was again presented. Sessions 14, 15, and 16 presented tones one, five, and three respectively. For Group 1-3-5, in all succeeding training sessions, tones one, three, and five were randomly alternated. During each training tone, reinforcement was contingent upon responding to the area corresponding to the tone in effect; responding to areas appropriate during other tones did not produce reinforcement. Throughout this training, a correction procedure was employed whereby a tone was not alternated until after a correct response.

The subjects in Group 1-3-5 continued on this procedure until they reached a criterion in which errors were fewer than 10% of the total responses during each tone, or until they had completed 60 sessions of training with the procedure. In the session following this criterion, the probability of reinforcement was decreased from 1.0 (*i.e.*, continuous reinforcement) to 0.5. However, each correct response produced the relay click while incorrect responses did not. This was continued for 20 sessions and then each subject was tested.

For subjects in Group 1-5 (S-108 and S-109), the training procedure was similar to Group 1-3-5 except that during training, only tones one and five were employed. Table 1 shows this modification. Group 1-5 learned to associate responses to the ends of the response surface during tones one and five.

Group 2-4 (S-112 and S-156) was also trained with a procedure similar to that employed with Group 1-3-5. As Table 1 shows, however, only tones two and four were employed during training for this group. When tone two was present, the appropriate response areas were 2a and 2b and when tone four was present, the appropriate response areas were areas 4a and 4b. Thus, these subjects learned a discrimination with values between those learned by the other groups.

Testing. Each subject was tested after 20 sessions on the 0.5 probability schedule of reinforcement. A random sequence of tones was presented during each test session. During the test, food continued to be delivered on the 0.5 schedule for correct responses during the tones employed in training. Also, each correct response during a training tone produced both the secondary reinforcer (*i.e.*, the click) and the intertrial interval. In the no-tone intertrial interval following these correct responses, the tones were randomly alternated. An incorrect response during a training tone produced the intertrial interval, but these responses were not followed by the click. On subsequent trials, the same tone was repeated until the subject emitted a correct response.

Each subject was also presented with test tones of values not employed during training. Group 1-3-5 therefore had test tones two and four; Group 1-5 had test tones two, three, and four; and Group 2-4 had test tones one, three, and five. Responses to any area during a test tone produced the click and caused the tones to alternate during the intertrial interval. This test procedure was continued for eight sessions.

RESULTS

Discrimination Training

Individual data for each subject in representative training blocks of four sessions each are shown in Table 2. Since the results for individual subjects within groups were similar, figures for representative subjects are presented throughout this study. Figures 2 and 3 show the results of discrimination training for each training condition. The reinforcement areas during each tone are labelled S+. Consecutive training sessions are presented in blocks of four sessions. During each session of Figures 2 and 3, training tones were alternated randomly from trial to trial.

Figures 2 and 3 demonstrate that with continued training, each stimulus gradually acquired stimulus control. A clear example of this increase in stimulus control is apparent in the data of S-124. In Block 1, during tone one, a large percentage of the responses were emitted to nonreinforcement areas. During Block 1, S-124 emitted 186 responses during tone one, but only 57 of these responses were emitted on areas 1a and 1b (see Table 2). Figure 2 shows that as training on tone one

Table 2
Responses per Area for each Subject during the First and Last Training Blocks

Group	Subject	Block	Tone	Response Areas									
				1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
1-3-5	S-114	1	1	49	8	10	18	11	17	3	2	2	16
			3	98	18	33	45	54	32	13	16	4	34
			5	35	8	13	13	24	14	24	8	9	48
		20	1	129	6	0	2	23	15	1	1	0	4
			3	23	3	3	27	73	68	18	3	0	16
			5	0	0	0	0	5	8	0	0	1	130
1-3-5	S-116	1	1	27	32	43	63	42	33	15	17	13	14
			3	49	46	50	52	47	38	35	20	17	26
			5	74	61	46	36	60	46	43	40	32	24
		20	1	70	57	37	27	39	37	11	1	1	4
			3	22	40	36	49	79	58	22	9	14	19
			5	5	7	3	10	29	24	20	12	18	103
1-3-5	S-124	1	1	51	7	8	16	40	32	25	19	25	14
			3	45	9	12	28	49	36	16	18	17	10
			5	36	2	6	19	27	30	23	20	28	28
		20	1	131	9	2	1	7	5	2	1	1	0
			3	6	4	2	10	51	93	49	15	5	23
			5	3	0	0	0	2	9	7	3	8	139
1-3-5	S-125	1	1	36	20	19	22	35	64	39	13	7	20
			3	50	28	25	38	44	41	24	17	6	25
			5	61	26	25	28	52	30	35	15	9	50
		20	1	89	41	18	19	42	21	10	1	2	6
			3	32	18	19	31	67	68	39	7	3	14
			5	1	0	2	0	15	8	3	0	0	135
1-5	S-108	1	1	95	28	5	7	1	1	2	5	12	52
			5	146	33	10	2	6	3	2	11	18	64
		12	1	180	20	1	0	0	0	0	0	0	19
1-5	S-109	1	1	96	7	12	4	0	1	2	16	18	96
			5	137	25	20	11	6	7	13	27	47	72
		12	1	172	24	5	3	2	0	0	0	2	7
2-4	S-110	1	2	26	32	52	44	78	63	74	41	16	2
			4	14	43	87	82	101	71	75	29	1	1
		20	2	2	26	110	92	11	1	11	9	3	0
2-4	S-156	1	2	10	19	51	49	36	37	65	49	26	2
			4	18	45	78	83	53	35	56	44	12	1
		20	2	3	12	80	141	86	21	11	15	1	0
			4	0	0	2	6	11	15	56	162	46	4

progressed from Block 1 to Block 15, more and more responses were emitted to areas 1a and 1b, while fewer responses were emitted to areas 2 through 5. Thus, in Figure 2, the response distribution became more peaked at

areas 1a and 1b from Block 1 through Block 15. Figure 2 shows that during training with tone three, the gradient became more and more peaked around reinforcement areas 3a and 3b from Block 1 to Block 15. With con-

Fig. 2. Discrimination training in successive blocks of four sessions for S-124 and S-125 of Group 1-3-5 trained on tones one, three, and five. The percentage of the total responses to the individual response locations during each tone is shown for successive blocks of training. Reinforcement areas during each tone are labelled S+.

tinued training, tone five gradients also became more peaked around reinforcement areas 5a and 5b. These trends are also apparent when the response distributions in Block 20 are compared to the response distributions during Block 1 (see Table 2). Similar examples of increased stimulus control with training can be found in the other figures. By the end of training, all subjects appeared to be responding under appropriate stimulus control.

Initially, errors during each tone occurred on all areas with equal frequency. With further training, however, errors to areas other than those associated with reinforcement tended to decrease. Graphically this can be seen most clearly in the training gradients of S-110 trained on tones one and five (see Figure 3). By Block 7, errors during tone one occurred most frequently to response areas 5a and 5b, the reinforcement area during tone five (see the slight peak at these areas in Figure 3). Errors during tone five were emitted primarily to the reinforcement areas for tone one (see the small peak at areas 1a and 1b). Mann-Kendall tests for trend reflected this observation. For areas 1a and 1b during tone five, the trend toward a decrease in responding was not significant at the 0.05 level of confidence during Blocks 1 to 7 for the subjects in this group. For the other error areas (2a through 4b) however, the decrease in responding over these blocks was significant ($S = -16$, $p < 0.05$). Most of this decrease in responding to intermediate areas was due to S-156 of Group 1-5, which emitted a number of responses to intermediate areas during the first two blocks of training. Figures 2 and 3 show that the same trend existed for the subjects of the other groups; most errors were emitted to reinforcement areas for other tones. As Table 2 shows, however, there were some responses on nonreinforcement areas for the subjects in Groups 1-3-5 and 2-4. For instance, during tone three in Block 20, S-124 emitted 10 responses (4% of the total tone three responses) to area 2b and 49 responses (11%) on area 4a. Thus, there was some spread of errors for this subject and, indeed, for the other subjects in this group. A similar spread of errors occurred in the response distributions of the subjects in Group 2-4 (see Table 2). Thus, while errors occurred primarily on reinforcement areas for other training tones, there were some errors on intermediate areas adja-

cent to the appropriate area during that tone.

Figure 2 also shows that there were slight individual differences in the final performance level for each subject. By the last block of discrimination training (Block 20), over 73% of the total responses of S-124 were correct. S-125, however, had a lower percentage of correct responses, 56%. Similar results were obtained for the other two subjects in this group. Thus, in Figure 2, the response distributions of S-124 were more peaked around the reinforcement areas (*i.e.*, the areas labelled S+) than those of S-125. There were also small individual differences for Group 2-4 during Block 20, where S-110 emitted a higher percentage of correct responses than S-156. Group 1-5, trained with tone one and tone five, did not show these individual differences. Both subjects in this group emitted over 90% correct responses by their last training block (see Table 2).

Group 1-5 was also the only group to attain the criterion of less than 10% incorrect responses during each tone before Block 15. Throughout training, S-108 from this group emitted few responses to intermediate areas. During pretraining and the first three blocks of discrimination training, an average of only 5.2% of the total responses were emitted to areas 2-4. During Blocks 4 to 12, errors to these areas averaged only 0.66% per block. Apparently, the discrimination for Group 1-5 was easier than for the other two groups.

The change of reinforcement schedule from continuous to a probability of 0.5 had little effect on responding during training. For Group 1-3-5 and Group 2-4, the change came after Block 15, while for Group 1-5 the change came after Block 7. Figures 2 and 3 show that the response gradients during each tone were almost unchanged in the last five blocks when the 0.5 schedule of reinforcement was in effect.

Testing

Figures 4 and 5 show the test results based on the total responses during each tone. In these figures, Pretest Blocks 1 and 2 present the response distributions during each tone in the last eight training sessions for each subject. Test Blocks 1 and 2 show the total percentage of responses during each training and test tone in the eight testing sessions. For Group 1-3-5, eight discrimination retraining sessions following the test (Posttest Blocks 1 and 2) are

Fig. 3. Discrimination training in successive blocks of four sessions for S-108 of Group 1-5 and S-110 of Group 2-4. The percentage of total responses to the individual response locations during each tone is shown for successive blocks of training. Reinforcement areas during each tone are labelled S+.

Table 3

Responses per area during the test tones for each Subject in test session 1 and in test blocks 1 and 2.

Group	Subject	Test		Test Tone	Response Areas								5a	5b
		Session	Block		1a	1b	2a	2b	3a	3b	4a	4b		
1-3-5	S-114	1		2	9	1	0	1	11	3	0	0	0	0
				4	0	0	0	0	6	3	0	0	0	20
				1	2	45	2	0	14	40	15	3	0	1
			1	4	1	0	0	4	18	15	8	0	1	95
				2	2	55	3	1	16	27	15	0	0	2
				4	2	0	0	3	9	14	0	0	1	116
1-3-5	S-116	1		2	2	7	6	10	6	2	0	1	0	6
				4	1	0	0	2	2	11	6	4	5	13
				1	2	16	25	18	23	35	6	2	2	17
			1	4	1	2	0	6	24	32	17	13	13	60
				2	2	7	16	16	17	35	24	3	7	5
				4	0	1	1	7	34	28	19	14	20	32
1-3-5	S-124	1		2	23	0	0	0	4	3	4	0	0	0
				4	0	0	0	0	4	4	8	0	0	26
				1	2	76	4	1	8	16	17	6	2	5
			1	4	1	0	0	0	14	19	20	8	9	80
				2	2	50	3	2	10	24	22	4	1	0
				4	3	0	1	2	19	20	13	5	7	59
1-3-5	S-125	1		2	9	1	2	3	4	13	5	0	0	0
				4	0	1	0	0	5	1	3	0	1	31
				1	2	25	9	5	15	24	38	20	3	4
			1	4	1	1	0	0	6	12	4	0	2	142
				2	2	33	3	7	6	45	43	14	1	1
				4	6	0	3	3	16	22	9	0	0	112
1-5	S-108	1		2	31	2	2	1	0	0	0	2	1	9
				3	26	2	0	0	0	0	0	0	2	20
				4	4	1	0	0	0	0	2	0	1	47
			1	2	102	19	8	1	0	0	2	4	6	76
				3	74	18	3	0	0	0	1	3	3	97
				4	18	7	0	3	0	0	4	4	12	178
1-5	S-109	1		2	125	41	3	0	0	0	0	3	7	41
				3	112	9	2	0	1	0	3	1	3	70
				4	23	5	1	0	1	0	2	6	8	183
			1	2	34	11	1	0	0	0	0	0	0	10
				3	24	5	4	0	1	0	0	0	0	26
				4	2	0	2	0	0	0	0	2	0	69
1-5	S-109	1		2	141	21	2	1	0	0	0	0	1	61
				3	110	17	8	0	1	0	0	0	1	94
				4	7	1	2	0	0	0	2	0	1	267
			2	2	109	29	4	1	0	0	0	0	0	56
				3	96	13	1	1	0	0	0	1	1	83
				4	7	11	1	1	0	0	0	0	1	224

Table 3—continued

Group	Subject	Test		Test Tone	Response Areas									
		Session	Block		1a	1b	2a	2b	3a	3z	4a	4b	5a	5b
2-4	S-110	1		1	0	0	21	13	5	0	3	3	1	0
				3	0	0	10	16	2	0	5	10	1	0
				5	0	1	1	2	1	0	5	26	8	0
			1	1	1	10	86	52	7	1	17	8	1	1
				3	1	9	64	60	9	2	30	43	3	1
				5	1	2	7	7	2	1	45	100	15	0
			2	1	1	16	76	47	3	3	19	19	1	1
				3	0	11	54	37	6	3	40	26	4	2
				5	0	2	18	10	2	1	54	93	14	0
2-4	S-156	1		1	0	1	9	16	9	4	2	2	0	0
				3	5	3	13	14	5	0	7	2	0	0
				5	1	2	4	7	3	3	9	15	3	0
			1	1	1	10	29	67	34	13	11	10	0	0
				3	5	7	37	48	26	16	26	38	2	0
				5	1	2	5	10	11	13	35	78	24	2
			2	1	0	9	59	62	17	0	3	4	0	0
				3	2	18	53	46	13	7	5	8	0	0
				5	0	2	15	15	12	10	29	66	7	0

also presented. Individual data during test tones for test session 1, and for the two test blocks are shown in Table 3.

The difficulty of the training problem had little effect on test results. Subjects in Group 2-4, which had a 25% error rate during the last eight training sessions, emitted responses during test tone three primarily to the areas associated with reinforcement during training (*i.e.*, areas 2a and 2b, and areas 4a and 4b). Few responses were emitted to the intermediate areas (3a and 3b), resulting in the valley in the gradients at these areas (see Figure 4). The subjects in Group 1-5, which had only a 10% error rate during the last eight training sessions, also emitted most of their responses during test tone three to the areas associated with reinforcement during training (*i.e.*, areas 1a and 1b, and areas 5a and 5b). Presumably if response mapping occurred, the response gradients for Group 1-5 during test tone two should resemble the response gradients of subjects in Group 2-4 during training tone two. Figure 4 indicates that the test gradients for the subjects in Group 1-5 and the training gradients for the subjects in Group 2-4 during tone two were quite different. Since S-108 of Group 1-5 emitted few errors to intermediate areas throughout training, these results were

not likely to be due to the extinction of responses to nonreinforcement areas. Thus, there is little evidence that problem difficulty and extinction influence the formation of a continuous repertoire.

The number of training problems also did not noticeably increase the amount of response mapping during test stimuli. Figure 5 shows that during test tone two, Group 1-3-5 responded primarily to the areas appropriate during tone one and tone three, their training tones. Few responses were emitted to area 2a and 2b, the appropriate areas if response mapping occurred. During tone four, Group 1-3-5 responded primarily on areas 3a and 3b, and areas 5a and 5b, the reinforcement areas during tone three and tone five. Few responses were emitted to areas 4a and 4b, the appropriate areas for response mapping.

There were large differences between the response distributions of subjects trained on a tone and for subjects tested with that tone. For instance, a comparison of test tone three response distributions for Group 1-5 and 2-4 showed that their response distributions were quite different from the response distributions of Group 1-3-5, trained with tone three (see Figures 4 and 5). During tone three, Groups 1-5 and 2-4 responded primarily on the areas

Fig. 4. Test response distributions in blocks of four sessions for S-108 trained on tones one and five and S-110 trained on tones two and four. Reinforcement areas are labelled S+. Pretest blocks 1 and 2 show the last eight sessions of discrimination training. Test blocks 1 and 2 show the response distributions during both training and test tones in the eight test sessions.

Fig. 5. Test response distributions in blocks of four sessions for S-124 and S-125 trained on tones one, three, and five. Reinforcement areas are labelled S+. Pretest blocks 1 and 2 show the last eight sessions of discrimination training. Test blocks 1 and 2 show the response distributions during both training and test tones in the eight test sessions. Posttest blocks 1 and 2 show the eight subsequent discrimination retraining sessions.

associated with reinforcement during training and few responses occurred to areas 3a and 3b (see Table 3). Group 1-3-5 was trained to respond on areas 3a and 3b during tone three and their response distributions were peaked at these values.

Table 3 shows that mapping responses were not extinguished by the test procedure. During the test, responses during training tones were reinforced with food on the 0.5 probability schedule. Responses during test tones were reinforced only with the explicit secondary reinforcer (*i.e.*, the click). The possibility existed that mapping responses during test tones were extinguished because no primary reinforcement was contingent on these responses. If this extinction occurred, then the proportion of mapping responses should have decreased over sessions. Comparing the results for the first test session with the results for Test Blocks 1 and 2 in Table 3 shows that the proportion of mapping responses did not decrease over test sessions. Therefore, extinction of mapping responses during testing cannot account for the obtained results.

During the test tones, the response distributions were similar to those that would be found if subjects were scaling stimulus similarity on two or three discrete standard experimental keys, rather than on a continuous response surface. For example, the responses of Group 1-5 were emitted primarily to areas 1a and 5b during all five tones (see Figure 4). If the subjects in Group 1-5 had been trained in an apparatus that had one key located at area 1a and a second key located at area 5b, responses to these two keys probably would have yielded a response distribution closely similar to that obtained with the continuous response surface of the present study. Similarly, subjects from other groups responded during test tones as if key areas intermediate to those trained did not exist.

The proportion of subjects' total responses during each test tone indicated the similarity between the test tone and the training tones. For instance, during test tone three, Group 1-5 responded approximately equally often to areas 1 and 5 (see Figure 4). However, during test tone two, a lower tone, a greater proportion of responses were emitted to area 1 reflecting the greater similarity of tone two to tone one than to tone five. During test tone four, a higher tone, Group 1-5 emitted the

greater proportion of responses to area 5. Thus, the test tone response distributions did show the similarity between test and training tones. Similar trends can be found in the other groups.

The problem of averaging, found in some previous studies, is readily illustrated by the calculation of the mean-response area for S-108 during test tone three. Figure 4 shows that S-108 of Group 1-5 responded almost entirely on areas 1a and 5b during test tone three, yet the mean response area for this response distribution was 3b. The use of mean response areas to present the present data would therefore be extremely misleading as to the actual response locations used by each subject.

Finally, the posttest response distributions for Group 1-3-5 (Figure 5) appear to be unchanged from the last two pretest blocks. Although the posttest data for the other two groups are not presented, their response distributions were similarly unchanged following the test blocks. Thus, the test procedure did not disrupt performance during training tones.

DISCUSSION

The present results seem unequivocal in showing no mapping of responses to stimulus values not used in training. A test stimulus not used during training does not increase the number of responses to intermediate response areas over that found when only training stimuli are used in the final sessions of training. This finding is compatible with the discrimination learning and response variability literature. After training several points of correspondence between a stimulus and response continuum, a test stimulus between two conditioned values evokes responses in one or another of the reinforcement areas during training, rather than in an intermediate area which would happen if a continuous repertoire had emerged finer than the one directly established in training. Thus, all responses are distributed around original conditioning points. There is no control by intermediate stimuli over intermediate response locations. This finding is then comfortably parsimonious with the stimulus control literature.

It is, nevertheless, possible that response mapping to new stimulus values would be demonstrated with somewhat different procedures than those used in the present study. If

testing had been done with extinction, rather than with reinforcement to maintain responding, perhaps more responses would have been emitted on intermediate areas during test tones. Studies in response variability that have used a continuous response surface but reinforced responses to any area (Antonitis, 1951; Herrnstein, 1961; Eckerman and Lanson, 1969) reveal considerable stereotypy during conditioning but during subsequent extinction find an increase in response variability. If the present study had extinguished responses to all areas during testing, response variability would probably have increased. However, there is nothing to lead us to the expectation that the increased responding that might have occurred to intermediate values would be controlled by the appropriate stimulus.

It is also possible that response mapping to intermediate stimuli was reduced by the use of only secondary reinforcement of responses to intermediate locations but primary reinforcement of responses to an original training area when appropriate to the stimulus. With such a procedure one might suspect extinction of intermediate responding during the test phase. However, as the results in Table 3 show, there is no evidence of a greater proportion of mapping responses early in testing than later in testing. Thus, extinction of mapping responses during testing is an unlikely explanation of the present results.

However, during the extensive training period, responding to intermediate areas did undergo extinction. Perhaps the extinction of responding to intermediate areas during training offset any tendency for intermediate stimuli to evoke intermediate responses. Subjects in Group 1-5, however, made relatively few responses to intermediate areas during training but showed no more mapping responses than subjects in other groups. On the other hand, it is possible that the strong position preferences shown by this group prevented both responses during training and responses during testing to the intermediate values. Although extinction of the intermediate response values is an intrinsic characteristic of conditioning by traditional discrimination procedures, it is possible that an errorless procedure, if developed, would provide response mapping to intermediate stimuli and thereby demonstrate that the present results are the result of

extinction of intermediate responses during an extensive training procedure.

While searching for different training procedures that might yield mapping to intermediate values is of interest, the present authors consider it most probable that mapping occurs only through reinforcing responses to given stimuli and that intermediate responding does not emerge by presenting stimulus values intermediate between values previously associated with reinforcement. Instead, the common situations involving continuous repertoires that seem so pervasive in everyday behavior may be the result of rapid acquisition. The earlier analysis of continuous repertoires (Holland and Skinner, 1961) placed heavy emphasis on the differential reinforcement derived from response-produced stimuli in a continuous repertoire. The behavior of the child learning to draw from copy is presumed to be reinforced by his marks on a paper to the extent that he discriminates the closeness of the approximation of his marks to the copy.

It would seem a fruitful direction of research to develop a discriminative matching repertoire before conditioning points on the stimulus dimension to points on the response dimension. Under these conditions it is anticipated that intermediate responding would be rapidly conditioned.

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