THE REMOVAL AND RESTORATION OF STIMULUS CONTROL¹

L. T. STODDARD AND MURRAY SIDMAN

MASSACHUSETTS GENERAL HOSPITAL

When a well-learned circle *versus* ellipse discrimination was made impossibly difficult for the subjects (rhesus monkeys), the controlling stimulus-response topographies were replaced by competing topographies. The identification of two training conditions sufficient to reinstate the original discrimination permitted the following inferences: the original controlling topography had merely decreased in probability of occurrence, whereas the "strength" of the stimulus-response relation remained unchanged; discriminations along the apparently continuous circle-ellipse dimension actually involved several distinct stimulus-control topographies.

Ray has offered evidence that topography and probability of an operant response have analogies in the topography and probability of a controlling stimulus-response relation. "When an organism learns to respond to a new stimulus, . . . this falls in the category of creating a new stimulus-response relation, a new stimulus-control topography" (Ray, 1969). Stimulus-control topography does not, of course, refer to a spatial configuration, but merely identifies the specific features of the stimulus (and the response) that comprise the actual behavioral unit. The term focuses attention on the *truly* controlling properties of the stimulus (and on the *actual* controlled response) rather than the stimulus and response as operationally defined in the reinforcement dependency. When the experimenter's definition and the actual controlling events are identical, "stimulus-control topography" and "controlling stimulus-response relation" are synonymous. The distinction is functional, not merely typological. It permits one to ask, of any change in stimulus control, whether that change involved a new stimulus-control topography or whether it represented only a change

in the probability of the original controlling relation. Ray suggested that once a controlling stimulus-response relation has been created, its probability of occurrence, like that of an operant response, may change without any alteration in its topography.

Changes in stimulus-control topography and probability pose formidable measurement problems (Ray and Sidman, 1970). One reason is the sheer difficulty—given any instance of a stimulus, response, or both—of knowing whether a particular form of stimulus control has actually occurred. It has been amply demonstrated that the mere presence of a stimulus whenever a response and reinforcement occur does not guarantee a controlling relation between that particular stimulus and response (Ray, 1967; Terrace, 1966). This is true whether the subject has undergone single-stimulus training, extra-, inter-, or intradimensional training. The stimulus-control topography that develops may involve other stimuli that are also (and inevitably) present, even random or uncorrelated stimuli; it may involve the specified stimuli, but other, unspecified, responses; and multiple sources of reinforcement may operate on completely unspecified stimulus-response relations. These ambiguities have contributed to uncritical usage of the concepts of *attention*, *excitation*, and *inhibition*, which more often than not provide only rationalizations for an experimenter's inability to measure the particular stimulus-control topographies with which he is concerned. The identification of actual stim-

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ulus control topographies, although it hardly requires a high level of theoretical sophistication, is a fundamental problem of research in stimulus control. The present experiment, while not solving this problem, will help demonstrate its importance.

Two recurring themes in the stimulus-control literature converge in this experiment. The first may be characterized by the question: is an existing stimulus-control topography affected by the occurrence of, the creation of, or other changes in more-or-less-related stimulus-control topographies? An early approach to this problem was Skinner's (1933; 1938, pp. 192-195). After establishing a successive click-no click discrimination ($S_1 - R \rightarrow$ Reinforcement; $S_2 - R \rightarrow$ Extinction), he abolished the discrimination by reinforcing responses to the negative stimulus ($S_2 - R \rightarrow$ Reinforcement), but did not present the positive stimulus (S_1) to the subject. He then asked about the controlling relation, $S_1 - R$: did it still exist? To answer this question, he continued to reinforce $S_2 - R$ until satiation had caused the animal to stop responding, and then he presented S_1 again. S_1 was invariably followed by a response. Although a new stimulus-control topography had been created by reinforcing responses to the former negative stimulus, the original controlling topography that included S_1 was still intact.

Blough (1969) was concerned with the question: "What makes a stimulus irrelevant?" He first reinforced responses to a particular compound of visual wavelength (L_1) and tonal frequency (F_1), and extinguished responses to all other combinations of wavelength ($L_1 \dots L_7$) and frequency ($F_1 \dots F_7$). Discrimination gradients demonstrated the existence of controlling relations along both the color and tone continua. The next step was to continue varying one type of stimulus, for example, $F_1 \dots F_7$, while keeping the other, L_1 , constant. Responses to the combination, $L_1 F_1$, continued to be reinforced. One result of this manipulation was nearly to eliminate any evidence of control by the colors; stimulus-control topographies that included the now "irrelevant" wavelengths were greatly reduced in their probability of occurrence. Control by colors, however, was not tested independently of tonal frequency to determine whether the topographies that included colors had changed in form as well as in probability. That is to say,

if Blough had presented the colors without the tones, would control by the colors have immediately reappeared? In this instance, changes in the original topographies seem unlikely, since the reinforcement dependencies were merely suspended, not altered.

Ray (1969) actually reversed the reinforcement dependencies for one set of stimulus-response relations in a compound associated with reinforcement, and did measure control by the individual stimulus elements. Using colors (C) and line tilts (T), she first established the following stimulus-control topographies: $C_1 - R_1$, $T_1 - R_1$, and the compatible compound $C_1 T_1 - R_1$; $C_2 - R_2$, $T_2 - R_2$, and the compatible compound $C_2 T_2 - R_2$. Then, while the stimuli were presented to the animal in compound, she reversed one set of reinforcement dependencies. For example, she now reinforced $C_1 T_2 - R_1$ and $C_2 T_1 - R_2$. The result, measured by presenting the stimuli in compound and in isolation, was that the unreversed color elements continued to control R_1 and R_2 as before; the reversed tilt elements either continued to control their original responses or exerted no control at all. Even though new reinforcement dependencies were in effect, and the probabilities of the old topographies decreased, new topographies involving tilts did not emerge. Ray's animals learned to "ignore" the reversed elements, just as Blough's animals learned to "ignore" the constant elements of the compound stimuli.

The experiments summarized above demonstrated that changes in the probability of a controlling stimulus-response relation need not signify a change in its topography. When a controlling relation is replaced by a competing or alternative topography, the original relation may still "exist", as does an operant response that is "displaced" by another. The present experiment, using yet another method to reduce the probability of a controlling stimulus-response relation, will help clarify what happens in such a situation, other than that the controlling relation simply stops occurring. To achieve such clarification, some procedures for reinstating the original topography were investigated.

The second stimulus-control theme to which this experiment directed itself is the interpretation of generalization gradients. It has been suggested that a gradient with less than infinite slope does not actually represent a contin-

uous function, but rather, serves as a clue to the existence of stimulus-control topographies other than, or in addition to, those being measured (Ray and Sidman, 1970; Sidman, 1969; Stoddard and Sidman, 1971). Examples of such interacting topographies and their effects on gradient slope have been described by Ray and Sidman (1970) and Sidman (1969). Stoddard and Sidman (1967) provided evidence suggesting that discriminations between a circle and relatively "flat" ellipses and between a circle and relatively "round" ellipses, do not involve the same controlling stimulus-response relations, even though all these stimuli fall along the same continuum and can yield an orderly generalization gradient (Stoddard and Sidman, 1971). The present experiment provided additional evidence that more than one stimulus-control topography contributes to a generalization gradient by demonstrating that the controlling relations that suffice to reinstate an abolished discrimination differ as one progresses along a generalization continuum.

METHOD

Subjects

Four adult rhesus monkeys (*macaca mulatta*) were maintained at 80% ($\pm 3\%$) of their free-feeding weights. All food was 1-g Ciba banana pellets (Monkeys R34 and R35) or 0.7-g D&G pellets (Monkeys R36 and R39), and added vitamins.

Apparatus and General Procedure

The experimental enclosure was 18 in. deep by 18 in. wide by 21 in. high (45.7 by 45.7 by 53.4 cm). Stimuli were projected from the rear via 35 mm slides onto a square panel of eight translucent response keys, mounted on one wall. Each key was 2 in. (5 cm) square separated by barriers 0.75 in. (1.8 cm) in width. The stimuli were black ellipses (Fig. 1) on a bright yellow background, or blank yellow keys without ellipses. When the animal pressed the key that contained the correct stimulus on a given array, chimes rang, a food pellet fell into a tray at the lower right of the panel, and all keys were darkened. The next stimulus array was presented 4.5 sec later. Solenoid-driven shutters controlled the presentation and removal of the stimuli. An incorrect press produced only the 4.5-sec intertrial interval (non-correction). The position of the correct key

Fig. 1. The ellipses used in the immediate history sets and test probes. The major (horizontal) axis of each ellipse was 1 in. Each ellipse is identified by its ratio of minor to major axis. The circle (1.00) was always the positive stimulus.

changed from trial to trial. Complete descriptions of the apparatus and general procedure are in Sidman and Stoddard (1966, 1967).

Remote Training History

In preliminary training, the animals were first trained to press a bright key that had a circle on it; all seven incorrect keys were dark (95% correct). Then, a progressive stimulus-transfer program (Sidman and Stoddard, 1966, 1967) taught the animals the following performances in sequence: to select the single key with a form (circle) on it from seven equally bright keys that contained no forms; to select the key with a circle from seven keys that contained 0.53 ellipses (95% correct); and finally, by gradually enlarging the size of the negative ellipses, to choose the circle from seven 0.91 ellipses on two successive trials. All animals learned the several discriminations to the indicated criteria and participated in an experiment involving generalization gradients (Stoddard and Sidman, 1971). In this experiment, the animals were also trained with ellipse sizes 0.93, 0.95, and 0.97, all larger than 0.91, and they demonstrated sharp gradients at these values. Although a circle was always on the correct key, the discriminations could be characterized, in succession, as: bright *vs* dark; circle *vs* blank key; circle *vs* relatively "flat" ellipse; and circle *vs* relatively "round" ellipse.

Experimental Procedures

Immediate history I: the impossible discrimination. Preliminary experimentation had demonstrated that presenting an animal with circles on all eight keys (circle *vs* circle) for 10 consecutive trials would cause it then to respond incorrectly when presented with a previously learned circle-*vs*-ellipse display. This seeming elimination of the circle-*vs*-ellipse discrimination, however, depended on the size of the negative ellipses; it was not possible to predict where in the progression of ellipse sizes (Fig. 1) the disruptive effect of the circle-*vs*-circle history would manifest itself. The first experimental task, therefore, was to find the smallest ellipse at which the circle-*vs*-circle history would disrupt the circle-*vs*-ellipse discrimination. The following procedure was designed to accomplish this.

At the start of the first session, and of all sessions thereafter, the animals received 10 circle-*vs*-circle trials. On each trial the animal faced eight circles, one on each key. The control circuitry arbitrarily coded one key to be correct; if the animal pressed it, the reinforcing events occurred. The position of the "correct" key changed from trial to trial to include six of the eight keys once, and the remaining two keys twice. If the animal pressed a "wrong" circle, only the intertrial period ensued.

After the tenth trial on the impossible discrimination, a single circle-*vs*-ellipse test trial followed immediately. Figure 2A illustrates a circle-*vs*-circle trial and a test probe. For all animals, the initial test probe had 0.74 ellipses as the negative stimuli. The reinforcer was delivered if the animal chose the circle. If the animal did choose the circle, it was assumed that its immediate history with the impossible discrimination had not disrupted the circle-*vs*-0.74-ellipse discrimination. The animal then received the 10 circle-*vs*-circle trials again, followed by a test probe that contained 0.77 ellipses, the next size in the series (Fig. 1). Three animals continued up the ellipse series in this manner—10 circle-*vs*-circle trials followed by a single test probe that contained ellipses one size larger than the preceding test—until each animal made its first error on a test trial. The error suggested that the immediate history of exposure to the impossible discrimination had disrupted control by the forms, and at that point the first major phase of the experiment

began—to determine whether training on a circle-*vs*-blank-key discrimination would restore the circle-*vs*-ellipse discrimination.

Immediate history II: circle vs blank keys. The following procedure was designed to examine the state of the circle-*vs*-ellipse discrimination after two types of immediate history—circle *vs* circle, and circle *vs* blank keys. When the first error on a test probe occurred after the 10-trial circle-*vs*-circle history, the animal immediately received eight circle-*vs*-blank-key trials. On each trial, one key had a circle on it, and the other seven keys had the same bright backgrounds but were empty of forms. In the eight trials the circle appeared once on each key, and reinforcement was delivered only when the animal pressed that key.

After the eight trials of circle-*vs*-blank-key training, still without interruption, the animal received the circle-*vs*-ellipse test again. This second test was identical in every respect to the previous one that had followed circle-*vs*-circle trials, including the key position of the circle.

Figure 2B illustrates a sequence of 10 circle-*vs*-circle trials, one test probe, eight circle-*vs*-blank-key trials, and one test probe. The 20-trial sequence comprised one test cycle. Five entire cycles were completed to verify whether the circle-*vs*-circle history did eliminate the test discrimination reliably, and if so, whether circle-*vs*-blank-key training reestablished it. Five cycles yielded a score on five test trials after each type of history.

If circle-*vs*-blank-key training did suffice to reinstate correct responding on the circle-*vs*-ellipse test trials, the next larger ellipse size was tested the same way, with five repetitions of the new test cycle.

When the immediate history of exposure to the circle-*vs*-blank-key discrimination failed to reinstate a circle-*vs*-ellipse discrimination, the second major phase of the experiment began—to determine whether training on the discrimination, circle *vs* "flat" ellipse, would restore the disrupted performance.

Immediate history III: circle vs 0.53 ellipse. When correct responding on the test discrimination was not reinstated by circle-*vs*-blank-key training, a form discrimination was substituted for it in the eight-trial segment of the cycle. In the eight trials, the positive circle was in every key once; the negative stimuli were seven 0.53 ellipses. The standard set of five

Fig. 2. Three types of immediate-history and test-probe cycles. A: circle *vs* circle followed by one test probe; B: circle *vs* circle and circle *vs* blank keys, each followed by one test probe; C: circle *vs* circle and circle *vs* 0.53 ellipse, each followed by one test probe. See text for details of recycling and test-probe ellipse sizes; here 0.74 ellipses are illustrated in A and 0.86 ellipses in B and C.

cycles was given, as illustrated in Fig. 2C; each cycle began with 10 circle-*vs*-circle trials.

If the immediate history with the circle *vs* 0.53 ellipses did suffice to reinstate correct responding on the test trials, the next larger ellipse size was tested the same way, with five repetitions of the new test cycle.

Sequence of procedures. The distribution of immediate-history types and test-trial ellipses across sessions differed among the four subjects. These differences were dictated by considerations of satiation, replication, and control for sequence effects. The actual sequence of procedures for each animal, session by session, is listed in Table 1.

RESULTS

The curves in Fig. 3 show the percentage of correct responses on the circle-*vs*-ellipse probe tests (as diagrammed in Fig. 2B and 2C) after each of the three types of immediate history. All of the test probes that followed a given kind of immediate history have been grouped for each size of negative ellipse. No consistent differences were observed as a consequence of the order of the animals' exposure to the different immediate histories. Each curve begins at the ellipse size where five-cycle test determinations were first made; data below that ellipse size were obtained only after the circle-*vs*-

Table 1

Sequence of procedures for each animal. The two left columns are divided by sessions; the right columns are divided according to the size of the negative test ellipses.

Monkey	Session #	Type of Cycle (Fig. 2)	Negative Ellipse on Test Probes	Number of Test-Probe Trials after Each Immediate History		
				Circle vs Circle	Circle vs Blank	Circle vs 0.53
R34	1	A	0.74	1		
		B	0.77	5	5	
	2	B	0.80	5	5	
	3	B	0.83	5	5	
	4	C	0.83	5		5
		B	0.83	5	5	
	5	B	0.86	5	5	
	6	C	0.86	5		5
		B	0.86	5	5	
	7	B	0.89	5	5	
	8	C	0.89	5		5
		B	0.89	5	5	
R35	1	A	0.74	1		
		A	0.77	1		
		A	0.80	1		
		B	0.83	5	5	
	2	B	0.86	5	5	
	3	C	0.86	5		5
		B	0.86	3	3	
	4	C	0.89	5		5
		B	0.89	3	3	
	5	C	0.91	5		5
		B	0.91	3	3	
R36	1	A	0.74	1		
		A	0.77	1		
		B	0.80	5	5	
	2	B	0.83	5	5	
		B	0.86	5	5	
	3	B	0.89	5	5	
		C	0.89	5		5
	4	C	0.89	5		5
	5	B	0.91	5	5	
		C	0.91	5		5
	6	C	0.91	5		5
		B	0.91	5	5	
R39	1	B	0.74	5	5	
		B	0.70	5	5	

circle history, based on a single test probe for each value of ellipse. The number of probe trials each data point in Fig. 3 represents can be derived from Table 1.

Immediate history I: the impossible discrimination. The solid black curves show that the impossible-discrimination history did disrupt the circle-ellipse discrimination, but the animals varied with respect to the test ellipse at which the disruption first occurred. For example, Monkey R34 (bottom frame of Fig. 3) made its first test-probe error when presented with the circle-*vs*-0.77-ellipse test, but responded correctly on the next four test probes at that level. When the test probes contained ellipse sizes of 0.80 and larger, however, the

circle-*vs*-circle history almost completely eliminated any evidence of the circle-ellipse discrimination. Monkey R35 showed almost complete disruption of the test discrimination at ellipse sizes of 0.83 and larger, but it is possible that the reliance on a single test trial in cycle type A prevented the disruption from being detected at smaller ellipse sizes. The upturn at the largest ellipse represented a change of only one correct response. Monkey R36 chose wrongly on only the first 0.80-ellipse probe, but its discrimination was considerably disrupted in the tests at 0.83 and higher. Monkey R39 appeared most sensitive to the immediate history of circle-*vs*-circle trials, showing complete disruption of the discrimination both at the initial 0.74-ellipse tests and at the 0.70-ellipse tests to which it was exposed next.

Immediate history II: circle vs blank keys. When immediate history I, circle *vs* circle, first eliminated control by the relevant stimulus—a specified circle-ellipse difference—control could be immediately reinstated by training the animal on the circle-*vs*-blank-key discrimination. This can be seen most clearly by locating the points at which the solid and broken lines are most divergent: Monkey R34 at the 0.80 test ellipse; Monkey R35 at the 0.83 test ellipse; Monkey R36 at the 0.86 test ellipse; and Monkey R39 at the 0.70 test ellipse. The circle-*vs*-blank-key history, however, lost its power to restore the test discrimination as the ellipses became larger.

Immediate history III: circle vs 0.53 ellipse. When the circle-*vs*-blank-key discrimination no longer reinstated the test discrimination, the circle-*vs*-0.53-ellipse discrimination was introduced (cycle type C, Fig. 2) for three of the animals. The dotted curves in Fig. 3 show that the circle-*vs*-0.53-ellipse history did restore a considerable degree of control by the relevant test-stimulus differences even after the circle-*vs*-blank-key history had lost its power to do so. Again, however, the circle-*vs*-0.53-ellipse training did not suffice to reinstate the test discrimination when the test ellipses were shifted further upward in size.

Summary of Test Results

(1) At some negative-ellipse size, an immediate history with the impossible discrimination (circle *vs* circle) disrupted control by the circle-ellipse difference. (2) An immediate history of circle-*vs*-blank-key training could suffice to re-

Fig. 3. Per cent of correct responses on all test-probe trials after each type of immediate history, as a function of ellipse size. (For Monkey R35, test scores based on only three test trials are omitted.)

store control by the circle-ellipse difference. (3) When an ellipse size was reached at which circle-*vs*-blank-key training no longer restored control by the circle-ellipse difference, circle-*vs*-0.53-ellipse training did so. (4) An ellipse size was eventually reached at which neither circle-*vs*-blank-key nor circle-*vs*-0.53-ellipse training restored control by the circle-ellipse difference.

Analysis of Errors

Table 2 presents the percentage of responses reinforced on the immediate-history trials themselves. When the immediate history was circle *vs* circle, reinforcement was no longer correlated with differences between the stimuli. Only if an animal learned something about the sequence of "correct" key positions could it produce reinforcers at greater than a chance level. None did so.

Table 2

Per cent of total responses reinforced during each type of immediate history.

Monkey	Circle vs Circle	Circle vs Blank Keys	Circle vs 0.53 Ellipse
R39	13	97	—
R34	11	99	91
R35	13	100	98
R36	14	98	96

Circle-*vs*-blank-key training reinstated correct responding during the immediate-history trials themselves, as did circle-*vs*-0.53-ellipse training.

Errors on impossible-discrimination trials. When experimenter-programmed stimuli fail to control correct responding, an alternative stimulus to which subjects are likely to respond is key position. During exposure to the impossible discrimination, position-based responding was observed in all animals, although the stability of this behavior pattern differed among them. Table 3 presents the percentage of responses to each key position in the 50 circle-*vs*-circle trials of each five-cycle set. The keys are numbered arbitrarily.

Monkey R34 developed the most stable and specific position-based response. In nine of 11 sets, at least 60% of this animal's circle-*vs*-circle responses were to a single key, starting with key 1, then shifting to key 3, and ending with a return to key 1. In each set of trials, at least 88% of all responses were to these two

key positions, except in the next-to-last set when key-2 responses appeared temporarily.

Monkey R39 chose key 2 most often during both sets of circle-*vs*-circle trials. Its preference, however, did not appear as exclusive as that of Monkey R34.

Monkey R36 demonstrated a shifting pattern of key-position frequencies. In five of the 10 sets of trials, more than 50% of its responses were to a single key. In three sets, two keys combined, and in two sets three keys combined to account for at least 50% of the responses. The location of the preferred keys changed often from one set of trials to the next.

Monkey R35 appeared to respond very little to key position, except in the second set of trials. The frequent shifts in key preference by other animals, however, suggested that Monkey R35, too, might have responded to particular keys, but that the preferred key lo-

Table 3

Per cent of responses to each key position during circle-*vs*-circle trials

Monkey	Ellipse Axis Ratio	Key Number							
		1	2	3	4	5	6	7	8
R34	0.77	86	4	2	0	0	6	0	2
	0.80	94	0	2	2	0	2	0	0
	0.83	100	0	0	0	0	0	0	0
	0.83	74	2	20	0	4	0	0	0
	0.83	28	0	70	0	2	0	0	0
	0.86	26	0	68	0	4	0	0	2
	0.86	30	2	60	2	4	0	0	2
	0.86	44	6	48	0	2	0	0	0
	0.89	36	6	54	4	0	0	0	0
R39	0.89	68	16	4	4	6	0	0	2
	0.89	86	6	8	0	0	0	0	0
	0.74	4	36	16	10	6	8	16	4
	0.70	8	48	14	18	2	4	0	6
R36	0.80	62	2	2	10	4	16	0	4
	0.83	22	6	6	8	6	16	24	12
	0.86	14	8	0	0	2	4	62	10
	0.89	12	0	4	0	8	6	32	38
	0.89	4	2	4	0	4	6	62	18
	0.89	6	4	0	6	12	22	32	18
	0.91	6	2	8	2	66	2	4	10
	0.91	22	0	14	6	32	6	10	10
	0.91	30	8	12	2	8	14	8	18
R35	0.91	54	0	6	12	6	20	2	0
	0.83	14	20	8	20	14	12	6	6
	0.86	6	2	2	4	12	20	4	50
	0.86	10	14	6	20	12	10	14	14
	0.89	22	4	4	26	6	10	6	22
	0.91	16	6	10	16	14	14	6	18

cations changed more rapidly than was detectable in 50-trial sets. Therefore, all 34 ten-trial circle-*vs*-circle runs were examined separately. It was found that at least 50% of the responses were to a single key in six of the 34 runs, and to a pair of keys in 28 of the 34 runs. In all 34 runs, Monkey R35 made at least 70% of its responses on no more than four keys. The specific key locations changed from run to run, but Monkey R35's responses were clearly related to key position.

None of the position-based response patterns, or shifts in the patterns, produced reinforcers at greater than chance frequency (Table 2). No animal learned the sequence of key positions that were coded as "correct". Furthermore, no animal learned to limit its responses to either of the two keys that were twice coded as correct and that would have guaranteed two reinforcers in each run of 10 circle-*vs*-circle trials. No animal failed to complete a run, or gave any other evidence of loss of procedural control, *e.g.*, intertrial responding or simultaneous pressing of more than one key.

Key position did not account for all the subjects' responses, nor did the position preferences remain consistent for individual subjects. Other stimuli that may have shared control with key position were not identified.

*Errors on test trials after the circle-*vs*-circle history.* The animals' errors on the test probes reflected the position preferences that had been generated by the immediate history. Instead of switching to the familiar circle-ellipse difference, they continued responding to key position.

Because of the shifting key preferences, comparisons of test-probe errors with circle-*vs*-circle errors were made separately for each five-cycle test set. The left side of Table 4 shows how frequently the keys chosen on test-probe errors matched: (1) the most preferred key in the circle-*vs*-circle trials; (2) one of the two most preferred keys; (3) one of the three most preferred keys; and (4) one of the four most preferred keys. Only keys chosen on at least 10% of the circle-*vs*-circle trials were included in the comparison. The table shows, for example, that 60% of Monkey R39's test-probe errors were on its most preferred circle-*vs*-circle key, and 70% matched the two most preferred keys; the remaining test errors were on non-preferred (less than 10%) keys. In general, the

Table 4

Percentage of times the probe-test errors matched the key preferences that were generated by the circle-*vs*-circle trials.

Monkey	Tests after Circle vs Circle Training				Tests after Retraining			
	Number of Most-Preferred Keys							
	1	2	3	4	1	2	3	4
R39	60	70	—	—	67	—	—	—
R34	69	84	—	—	77	91	—	—
R35	23	36	54	69	17	43	64	75
R36	43	65	76	—	58	75	79	88

variability in the location of test-probe errors matched the variability of the animals' circle-*vs*-circle preferences.

Errors on test trials after retraining on circle vs blank key, and circle vs 0.53 ellipse. The animals' test errors after retraining were similarly related to the circle-*vs*-circle key preferences, as may be seen in the right side of Table 4. Thus, when retraining failed to reinstate the test discriminations, the subsequent test errors tended to match the animals' key preferences, generated by the impossible discrimination, and to which they reverted even after the correct retraining trials.

Errors on retraining trials. In a combined total of 1128 trials on both retraining procedures, the four animals made only 30 errors. Even most of these few errors could be traced to the animals' preceding error histories: 11 occurred on the first trial of a retraining run; five more occurred as consecutive errors starting on trial 1 or 2 of a retraining run; 13 of these 16 errors, and five more that occurred in mid-run, were made on the most favored key positions. Only nine retraining errors could not be interpreted as direct continuations of the key preferences that had been generated by the impossible-discrimination history.

DISCUSSION

The experiment succeeded in eliminating evidence of a simultaneous circle-*vs*-ellipse discrimination by presenting the subjects with only the positive stimulus (circle) on each key of the display. In the experiments of Blough (1969) and Ray (1969), which made previously controlling stimuli irrelevant by means of different but related techniques, the original

stimulus-control topographies were replaced by other topographies that had been concurrently reinforced. In the present experiment, no other topographies had been systematically reinforced, and the animals adopted key-position preferences. The eight-key stimulus-response panel increases the likelihood of identifying error patterns of this sort, and facilitates interpretation of the data (Sidman and Stoddard, 1967; Stoddard and Sidman, 1967).

Responses to key position need not, and probably did not, include responses to the circle *qua* circles. It is possible and likely that the animals responded to particular positions without attending to the stimuli on the keys at all, simply observing the presentation of the bright display with the accompanying apparatus sounds that marked the onset of a trial.

After the animals had adopted position-based behavior patterns that were not related to the stimuli on the keys and, therefore, not compatible with their well-established circle-*vs*-ellipse discrimination, the differences between the test stimuli failed to control their responses. When, during each set of eight retraining trials, their behavior again came under control of experimenter-programmed stimuli and, therefore, was systematically related to stimuli on the keys, they did respond then to the test-form differences. The original controlling relation was reinstated. The alternate establishment and removal of an error pattern helped to influence whether or not the familiar stimuli controlled the subjects' behavior.

This rapid reinstatement of the original controlling relation strongly suggested that the original topography had merely decreased in probability of occurrence, probably remaining unchanged in form. The result is in agreement with Ray's (1969) suggestion that a controlling stimulus-response relation is not necessarily modified when it occurs more or less often; the frequency of occurrence may not adequately reflect the "strength of the bond" between a stimulus and response.

If frequency of occurrence need not measure "strength of bond", one may question the appropriateness of calling a generalization gradient an "excitatory gradient". Empirically, a gradient records the frequency of occurrence of several stimulus-control topographies. A usual assumption is that all these topographies share the response in common, and differ from each other only with respect to quantitative

variations in attribute *x* of the controlling stimulus. Based on the latter assumption, a gradient of less-than-infinite slope is considered to arise simply because variations in attribute *x* of the reinforcement-associated stimulus exert corresponding variations in control over the measured behavior. But Prokasy and Hall (1963) suggested that the reinforcement-associated attribute either does or does not control the behavior; intermediate probabilities mean that other, unmeasured stimuli—attributes other than *x*—are the ones in control. Ray and Sidman (1970) and Sidman (1969) presented evidence consistent with this suggestion, illustrating the effects of competing forms of stimulus control on gradient shape. Cumming and Eckerman (1965), Migler (1964), and Migler and Millenson (1969) have shown that intermediate rates in generalization gradients may be the result of the alternation of several distinct responses, even though the controlling stimuli may actually be those specified. Thus, the several stimulus-control topographies involved in a generalization test may actually differ from each other not merely in the stimulus and response attributes specified by the coordinates of the gradient, but in attributes that the gradient does not even measure.

Because all of the differences among the test stimuli on an experimenter-specified continuum need not have participated in the same stimulus-control topography, Stoddard and Sidman (1971) suggested that it is a mistake to view generalization gradients as continuous functions. To demonstrate further the existence of hidden discontinuities in presumably continuous gradients, they appealed to the well-documented finding that gradients may be sharpened by giving the subjects discrimination training at stimulus values that are closer together on the continuum. This finding means that after a subject has learned to discriminate two stimuli widely separated on a continuum, new learning must take place before it can make finer discriminations; that is to say, new topographies must replace the original ones.

The present experiment, by identifying those topographies which sufficed to reinstate the discrimination as the ellipses came more closely to resemble the circle, permits one to infer the existence of different stimulus-control topographies along the circle-ellipse con-

tinuum. Retraining the animals simply to discriminate a key with a circle on it from blank keys—a “form-*vs*-no-form” discrimination—was enough to reinstate the easier circle-*vs*-ellipse discriminations. It is conceivable that a training procedure that used any form at all on the positive key would have had the same effect. The important point is that the same retraining procedure failed to reinstate the more difficult circle-*vs*-ellipse discriminations; the animals had learned something different about small and medium-sized ellipses, relative to the circle.

When form-*vs*-no-form retraining failed to reinstate control by the differences between the circle and intermediate-sized ellipses, retraining with a circle and flat ellipse succeeded. Again, it is possible that a retraining procedure using any two (or more) forms might have succeeded. A task that requires the subject to examine two or more keys in order for it to detect stimulus differences is more like the task required by the test than simply the behavior of looking for the form on one key. But “scanning and comparing”, by itself, was not the only factor involved, as was indicated by the failure of circle-*vs*-flat-ellipse retraining to reinstate the most difficult discriminations. This failure also demonstrates the superficiality of explaining the findings in terms merely of transfer after extradimensional and intradimensional training. The important point, again, is that the animals had learned something different about the intermediate-sized and largest ellipses relative to the circle.

The initial success and eventual failure of the two retraining procedures, in turn, demonstrated the probable existence of at least three different stimulus-control topographies along the circle-ellipse continuum. A gradient of control by the members of this continuum (Stoddard and Sidman, 1971), therefore, does not simply represent a continuous “excitatory” function. When points on this, and, by inference, on any gradient, show probabilities of less than 1.00 or greater than 0.00, the appropriate experimental strategy is to analyze the actual stimulus-control topographies, not to theorize about excitatory or inhibitory control by stimuli that may actually not control at all.

A final speculation is, perhaps, in order. The present experiment, as well as those of Blough (1969) and of Ray (1969), demonstrated that when a stimulus-control topogra-

phy is no longer reinforced, other topographies replace the original one. Extinction is an extreme instance of a breakdown of the correlation between stimulus control and reinforcement. Therefore, generalization tests during extinction are highly likely to generate fluctuations in stimulus control. Such fluctuations can be expected to be transient and extremely difficult to detect because the alternative topographies are not “caught” and maintained by reinforcement (Ray and Sidman, 1970).

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