*DOES CONDITIONAL DISCRIMINATION LEARNING BY
PIGEONS NECESSARILY INVOLVE HIERARCHICAL
RELATIONSHIPS?*

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Four experiments demonstrate that when putative conditional and discriminative cues are presented simultaneously in the single reversal procedure, it is not possible to ascribe a uniquely conditional or uniquely discriminative function to either of the cues. In Experiment 1, pigeons were trained to respond to a blue key and not to a red key while the houselight was on; then in a different session they learned the reversal of this discrimination with the houselight off (single reversal). Separate groups were tested for color generalization with houselight conditions alternating in blocks of trials or for houselight intensity generalization with blue and red key colors alternating in blocks of trials. Both test procedures revealed a conditional relationship between houselight and key color conditions. Experiment 2 produced the same result following training in which the key colors were held constant across training sessions while the houselight and no houselight conditions varied within sessions. In Experiment 3, separate groups were trained with the two procedures but were tested with randomly ordered combinations of key colors and houselight intensities. The two groups yielded indistinguishable bidimensional generalization gradients with peaks at both previously reinforced stimulus combinations. In Experiment 4 the subjects were switched from one of these training procedures to the other with no decrement in their discriminative performance. We conclude that for successive discriminations between conditional- and discriminative-stimulus combinations, the notion of a hierarchical relation between conditional and discriminative stimuli must be extended to include a symmetrical relationship or the notion should be abandoned altogether.

Key words: conditional stimulus, discriminative stimulus, generalization, color, line angle, key peck, pigeons

Sidman (1986) recently has defined a conditional discrimination as involving a four-term contingency whereby a conditional stimulus (e.g., a houselight in the operant chamber) designates which of several discriminative stimuli (e.g., key colors) signals the availability of reinforcement for a particular operant response. Conditional stimuli are said to control responding indirectly by virtue of the significance that they impart to other stimuli. Cumming and Berryman (1965) proposed that a conditional cue functions as a "selector of discriminations," that is, it provides "instructional control." Behavioral evidence of conditional stimulus control consists of differential discriminative stimulus control in the presence of different conditional stimuli.

A problem for the definition of conditional stimulus control is that it does not specify a priori which stimulus will play a conditional role and which will play a discriminative one.

It is traditional that discriminative stimuli for pigeons be visual cues projected on the response key, but this is not a logical necessity. Indeed global environmental cues such as the color of the houselight, the tilt of the floor, and the frequency of a tone have been used successfully.

If conditional and discriminative stimuli cannot be distinguished on the basis of their physical characteristics, can they be distinguished on the basis of their temporal ones? In some conditional discrimination paradigms, one of the stimuli comes on before the other, as in the matching-to-sample procedure. It is traditional to view the sample as a conditional cue that determines the significance of the subsequently presented comparison stimuli. Those comparison stimuli seem more directly related to behavior and are certainly more proximal to reinforcement.

An interesting procedure for studying conditional discrimination learning is the single reversal procedure, as used by Thomas, McKelvie, Ranney, and Moye (1981, Experiment 2). This procedure may be fruitful in revealing general principles of conditional discrimination learning because it is logically the

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simplest procedure capable of producing such learning and because it is highly efficient. In the Thomas et al. experiment, pigeons first were trained to respond to one of two successively presented key colors while the houselight was on; subsequently in a different training session they learned the reversal of the key color discrimination with the houselight off. This single reversal procedure was successful in establishing a conditional relationship between houselight and key colors, as shown in a subsequent generalization test. In this test, five different colors were ordered randomly within blocks and the houselight was switched on or off in alternating blocks of key colors. For every subject the key color gradients, obtained under extinction conditions, each peaked at the key color appropriate to the houselight condition present at the time. Furthermore, this result was achieved with a total of approximately 2.5 hr of training time.

Thomas et al. (1981) claimed that the houselight cues played a conditional role by determining the significance of the key colors. This claim seemed justified on the basis of both the test results and the training procedure that had been used. Consider first the training procedure. There can be no question that behavior was more directly related to the key colors than to the houselight conditions. Within sessions, key colors were differentially associated with presence or absence of reinforcement and responding varied accordingly. Thus, the key colors were explicit discriminative cues during training. On the other hand, there was no evidence of a possible discriminative role for the houselight conditions during training. At no point within any session was responding controlled directly by the presence or the absence of the houselight.

The logic of the single reversal training procedure strongly suggests that the cue held constant within training sessions serves a conditional function by indicating the significance of those cues that vary within sessions. The test procedure used by Thomas et al. (1981) was consistent with that interpretation, and it produced data that were also consistent with it. It must be recognized, however, that the sequencing of the combinations of houselight and key color conditions used in testing was entirely arbitrary and was not dictated by the training procedure. If Thomas et al. had trained their subjects as they did but had tested them

by varying houselight intensity *within* blocks of test trials while alternating key colors *across* blocks they might have reached a different conclusion altogether. If the obtained gradients were to peak at the houselight intensity appropriate to the key color that was present, this would suggest that the key color, rather than the houselight condition, had acquired a conditional function.

This interpretational problem is not unique to the use of the single reversal paradigm but applies to any procedure in which putative conditional and discriminative cues are presented simultaneously. In Lashley's (1938) classical experiment on "conditional reactions," rats were trained to choose an upright rather than an inverted triangle when the two stimulus cards had plain backgrounds but to choose the inverted triangle when the backgrounds were striped. Lashley viewed the backgrounds as conditional stimuli, and he did not test the rats with two upright triangles presented on a single trial with differing backgrounds. Had he done so, is it not possible that the rats would have chosen the card with the plain background?

In the present set of experiments we ask whether control along the dimension of the putative "conditional" stimuli (i.e., those held constant across sessions of training) differs from control along the dimension of the explicit "discriminative" stimuli (i.e., those which vary on a minute-by-minute basis within sessions). If no differences can be found, it would suggest that the distinction between conditional and discriminative functions of stimuli is untenable in the single reversal paradigm.

EXPERIMENT 1

Method

Subjects. Twelve experimentally naive pigeons were obtained from a local supplier and maintained at 80% of their ad-lib weights. They were housed in individual cages in a colony room with a 16:8 hr light/dark cycle. Light onset was at 7:00 a.m., and sessions were conducted 5 days per week.

Apparatus. The experimental chambers were four sound-attenuating ice chests bisected by aluminum intelligence panels. The subject's compartment was 26.5 cm long by 28.6 cm wide by 24.1 cm high. Access to the solenoid-operated food hopper was through an aperture

(3.8 cm high by 5.1 cm wide) centered on the intelligence panel 7.6 cm above the floor. The 1.9-cm diameter translucent key was located 11.4 cm above the hopper and required 0.12 N force to operate. The houselight in the experimental chamber consisted of a GE 1820 bulb behind a 4-cm frosted Plexiglas strip that was at the top of and covered the full length of the intelligence panel. The intensity of the houselight was controlled rheostatically and could be set at four different values. These values were 5.0, 3.7, 1.3, and 0 footcandles, as measured with a Simpson® Illumination Level Meter (Model 508) at a point directly in front of the response key. The houselight on (HL) and houselight off ($\overline{\text{HL}}$) conditions used in training were the 5.0 and 0 footcandle values, respectively. A white noise generator provided masking noise throughout training and testing. Key stimuli were produced by IEE® projectors (Series 0010) with no. 1820 lamps operated at 24 V. Kodak® Wratten Filters nos. 75, 74, 99, 73, and 72B produced nominal peak-transmitted wavelengths of 490 nm, 538 nm, 555 nm, 576 nm, and 606 nm, respectively. Reinforcement was 3-s access to the food hopper filled with mixed grain. Recording and control were accomplished with the use of a Commodore Pet Professional® computer (Model 2001) with a locally designed and constructed interface.

Procedure. The training procedure was the same for all subjects. During Phase 1 of training the houselight was on during all trials (HL). On the first day all subjects were magazine trained, and the key peck was shaped while the key was illuminated by a (blue) light of 490 nm. Next, for several days reinforcers were earned on a variable-interval (VI) reinforcement schedule with gradually increasing interreinforcement intervals. Then the subjects received successive discrimination training in which responses to the blue light were reinforced on a VI 30-s schedule, whereas responses to the red light (606 nm) were extinguished. Sessions were 30 min in duration. Trials were 55 s long with intervening 5-s blackout periods during which both the houselight and keylight were turned off and reinforcement was unavailable. The red and blue stimuli occurred in a nonsystematic order, except that each value appeared 15 times within each session.

After six sessions of Phase 1 discrimination

training, Phase 2 was initiated. The Phase 2 problem was the reversal of the Phase 1 problem, that is, S+ was now red and S- was blue. The houselight was off ($\overline{\text{HL}}$) during all trials of Phase 2 training. Subjects were studied for six sessions of Phase 2 discrimination training with the same trial and blackout durations as in Phase 1. Again the S+ and S- values appeared equally often in nonsystematic order.

On the day after completion of their Phase 2 training, the subjects were assigned randomly to Groups 1 and 2 for generalization testing in extinction. For subjects in Group 1, the five wavelength values of 490 nm, 538 nm, 555 nm, 576 nm, and 606 nm were ordered randomly within blocks of 10 stimuli, two of each value. The subjects were exposed to four such blocks, with half starting under each houselight condition, and the houselight conditions were alternated after each block. For subjects in Group 2, the four houselight intensity values of 5.0, 3.7, 1.3 and 0 footcandles were ordered randomly within blocks of eight stimuli, two of each value. There were four such blocks for each subject, with half starting under the blue key color condition and half under the red. These key colors were alternated after each block of houselight intensity stimuli. During generalization testing for both groups, trials and blackouts were of the same duration as during training.

Results and Discussion

By the sixth training session, each subject yielded greater than 90% of total responses during S+ periods of the Phase 1 discrimination. The introduction of the reversal (Phase 2) disrupted responding which, in some subjects, had to be reshaped in the $\overline{\text{HL}}$ context in the presence of the new S+, red. There were no subsequent differences in performance between those subjects that required reshaping and those that didn't. All subjects mastered the reversal problem, with responding to S+ exceeding 90% by the sixth training session.

Figure 1 presents the individual and group mean generalization gradients of the subjects in Group 1. Recall that these subjects were tested in a manner consistent with their training experience, that is, the houselight was held constant across sessions during training and within blocks during testing. There was clear evidence for conditional control by the house-

Fig. 1. Individual and group mean wavelength generalization gradients in two different houselight conditions following single reversal training in Experiment 1.

light condition over discriminative performance, that is, in each case the wavelength gradients peaked at the (S+) value appropriate to the houselight condition that was present. This was true even in the case of Z11, which responded substantially to both red and blue stimuli under both houselight conditions. The finding of strong conditional control replicates that originally reported by Thomas et al. (1981, Experiment 2).

The houselight intensity generalization gradients for the subjects in Group 2 also show strong evidence of conditional control (Figure 2). The gradients peak at the value appropriate to the key color that is present. Because the key color was held constant within blocks of test stimuli, it could be asserted that in this group the key color exercised conditional control over discriminative performance during testing. It acquired the capacity to do so via a training procedure in which its role was explicitly discriminative in that it varied on a

minute-by-minute basis and signaled the availability of reinforcement for key pecking.

Perhaps we should not be surprised that the key colors acquired a conditional function in this experiment. After all, responding was reinforced in the presence of HL only when the blue keylight and not the red keylight was present and the key colors had developed demonstrable control over behavior. Perhaps we should be more surprised that HL and $\overline{\text{HL}}$ gained conditional control because they were never varied within a session and provided no critical information during training. Thomas (1985) however, has pointed out that stimuli need not provide critical information in order to acquire discriminative control over behavior, in the sense of changes in the stimulus correlated with changes in response rate. The mere presence of the stimulus during reinforced responding may suffice, as in the case of a particular floor tilt in a study by Riccio, Urda, and Thomas (1966). These investi-

Fig. 2. Individual and group mean houselight intensity generalization gradients under two different key color conditions in Experiment 1. Note that the key color had been the explicit discriminative cue during single reversal training.

gators demonstrated that when pigeons are trained to peck a key with VI reinforcement with the floor in the normal horizontal position or tilted 30° from horizontal (in different groups), decremental generalization gradients are obtained when the floor tilt is systematically varied from its training position. What applies to discriminative control may apply to conditional control as well (i.e., mere presence may be all that is required).

Experiment 1 contained 6 hr of discrimination training, 3 on each problem. In the original study by Thomas et al. (1981, Experiment 2), approximately 2.5 hr of training time was sufficient. This is far less than what has usually been required in studies of operant conditional discrimination learning (see Borneau & Honig, 1964; Richards, 1979). One reason is certainly the extreme salience of both the houselight and key color cues used in these experiments. In recent experiments using floor tilt and key color cues (see Thomas, Stengel,

Sherman, & Woodford, 1987) and houselight and auditory frequency cues (see Thomas, Curran, & Russell, 1988), even extensive single reversal training failed to produce evidence of conditional control. A second reason is inherent in the single reversal procedure itself. In an experiment using the same houselight and key color cues as in the present study, Thomas and Goldberg (1985) showed that the traditional procedure of presenting the four stimulus combinations on a minute-by-minute basis within sessions during training led to poorer performance than a single reversal carried out after the initial problem had been mastered. Presumably this is because of interference generated by the within-session procedure (i.e., a cue that signaled reinforcement on trial n signaled extinction on trial $n - 1$). Clearly the optimal training procedure must balance the benefits of frequent comparisons of the training stimuli against the interference produced by changed contingencies within ses-

sions, and the need for stimulus comparisons should vary with the inherent salience of the stimuli. In the studies mentioned earlier using floor tilt or auditory frequency cues, frequent alternations of the stimuli were required for success, whereas with houselight and key color cues a single alternation is sufficient and frequent alternation of conditions may even prove harmful.

On the basis of the results of Experiment 1, one could claim a conditional (and/or a discriminative) role for both the houselight and the key color stimuli. In Experiment 2 we show that this result is not caused by the use of a training procedure in which the houselight was held constant across sessions while the key colors were varied within sessions. In this experiment, the roles of the two cues were switched relative to what they were in Experiment 1 (i.e., the key color was held constant across sessions while the houselight conditions provided the explicit discriminative cues).

EXPERIMENT 2

Method

Subjects and apparatus. The subjects were 12 experimentally naive pigeons maintained as in Experiment 1. The apparatus was the same as that used in Experiment 1.

Procedure. All subjects were trained in the same procedure. During Phase 1 of training the blue keylight was present on all trials. On the first day all subjects were magazine trained and the key-peck response was shaped in the presence of the blue key and the houselight. Responding was reinforced over several sessions according to a VI schedule with gradually increasing interreinforcement intervals. Then the subjects received successive discrimination training in which responses in the presence of the S+, HL, were reinforced on a VI 30-s schedule whereas responses in the presence of the S-, HL, were extinguished. Trial and blackout durations throughout training and testing were the same as in Experiment 1.

After six sessions of Phase 1 discrimination training, Phase 2 was initiated. The Phase 2 problem was the reversal of the Phase 1 problem, and the red keylight was present on all trials.

After six sessions of reversal training the subjects were assigned at random to two groups for generalization testing in extinction. For

Group 1 the test procedure was consistent with training in that the key color was held constant within trial blocks while the houselight intensity was varied. The test was identical to that used with Group 2 in Experiment 1. For Group 2, however, as for Group 1 in Experiment 1, the houselight was held constant within blocks during generalization testing while the key color was varied.

Results and Discussion

By the sixth training session, each subject yielded greater than 90% of total responses during S+ periods. Thus, the houselight condition, a global environmental cue removed from the site of the operant response, may readily serve as an explicit discriminative cue for pigeons. The introduction of the reversal task (Phase 2) disrupted responding slightly, but most subjects began responding to the red keylight within the first minute or two. Those that didn't were reshaped to peck the key. All subjects mastered the reversal problem, with responding to S+ exceeding 90% by the sixth training session.

Figure 3 shows the individual and group mean gradients of subjects in Group 1. The houselight intensity gradients peak at the (S+) value appropriate to the key color that was present. This result justifies the claim that the key colors gained conditional control over the houselight intensity discriminations that had been acquired in their presence. This result is noteworthy because in an earlier study Thomas, McKelvie, and Mah (1985) observed that in the single reversal paradigm key color had failed to gain conditional control over discriminations based on lines of differing orientation presented on the same key. One of the interpretations that they offered for this failure was a "stimulus configuring" interpretation. If the line-on-color stimulus were viewed as a perceptual unit or Gestalt, this might retard or preclude the perception of a conditional relationship between its constituent elements. The fact that key color was successful when used in conjunction with a discriminative cue with which it is unlikely to be configured (i.e., houselight) is consistent with this configuring interpretation of the earlier experiment.

Figure 4 shows the wavelength generalization gradients of Group 2. All subjects showed strong evidence of conditional control by the

Fig. 3. Individual and group mean houselight intensity generalization gradients in two different key color conditions following single reversal training in Experiment 2.

houselight over discriminative performance despite the fact that the houselight had served an explicit discriminative function during training.

The testing procedure in which one stimulus is held constant within blocks while another stimulus is varied is predicated implicitly on the assumption that the stimulus that is held constant within blocks is *the* conditional cue. As the results of these experiments show, however, the selection of which stimulus to hold constant and which to vary is an arbitrary one that need have no relationship to the roles explicitly played by these stimuli during single reversal training. Indeed it is possible to test for conditional control in such a way as not to presume that a given cue plays only one of the two roles. This was done in Experiment 3, which is, in a sense, a complement to Experiments 1 and 2. Whereas in those experiments groups that underwent the same training experience were tested differently, in Experiment 3 groups of subjects that were trained

with the two different procedures were tested with a single procedure.

EXPERIMENT 3

Method

Subjects and apparatus. The subjects were 16 experimentally naive pigeons maintained as in Experiment 1. The apparatus was the same as that used in Experiment 1.

Procedure. The subjects were divided at random into two groups of 8 birds each. For Group 1 the training procedure used was the same as in Experiment 1, that is, the houselight conditions (HL and $\overline{\text{HL}}$) were held constant across sessions, and the blue and red key colors were the explicit discriminative cues. The training procedure used with Group 2 was the same as that used in Experiment 2: The key colors (blue and red) were held constant across sessions, and HL and $\overline{\text{HL}}$ were the explicit discriminative cues. As in the earlier experiments,

Fig. 4. Individual and group mean wavelength generalization gradients under two different houselight intensity conditions in Experiment 2. Note that the houselight intensity had been the explicit discriminative cue during single reversal training.

six sessions of Phase 1 training were followed by six sessions of Phase 2 (reversal) training.

The subjects in both training groups experienced the same generalization test in extinction. The test consisted of six blocks of nine test stimuli. Within each block each of three houselight intensities, 5.0, 1.3, and 0 footcandles, was combined with each of three key colors, blue (490 nm), green (555 nm), and red (606 nm). These nine stimulus combinations were ordered randomly within the blocks. Throughout training and generalization testing in extinction in this experiment, as in the preceding two experiments, trials were of 55-s duration separated by 5-s blackouts.

Results and Discussion

The subjects in both groups mastered both their Phase 1 and Phase 2 discrimination problems, with greater than 90% of total responses to S+ on the sixth day of training in all cases.

There was some disruption of performance (particularly in Group 1) on the first day of Phase 2 training. Reshaping to peck was necessary for some subjects.

Individual generalization gradients are presented for subjects from Group 1 in Table 1 and from Group 2 in Table 2. The mean gradients of the two groups are shown in Figures 5 and 6. The figures show strong evidence of conditional control in that the bidimensional gradients peak at those stimulus combinations that signaled the availability of reinforcement with responding decreasing with changes from those values along both stimulus dimensions. As in Experiments 1 and 2, it is impossible to tell from the results of generalization testing which of the two training procedures any particular subject had been exposed to. Testing in the manner used in Experiment 3 makes it obvious that there is no way to justify designating one of the cues as exclusively condi-

Table 1
Generalization gradients of Group 1.

Subject	House-light intensity (foot-candles)	Key color (nm)		
		490	555	606
S1	0	3	27	653
	1.3	78	5	163
	5.0	406	0	9
S2	0	9	137	948
	1.3	220	36	132
	5.0	521	1	39
S3	0	9	88	804
	1.3	518	43	418
	5.0	582	11	103
S4	0	0	41	502
	1.3	145	3	199
	5.0	319	5	53
X9	0	1	24	223
	1.3	38	11	61
	5.0	331	1	57
X24	0	4	12	372
	1.3	40	0	142
	5.0	402	0	28
X26	0	1	8	471
	1.3	127	1	203
	5.0	333	1	116
X31	0	2	13	375
	1.3	97	0	212
	5.0	370	0	69

Table 2
Generalization gradients of Group 2.

Subject	House-light intensity (foot-candles)	Key color (nm)		
		490	555	606
X34	0	8	24	584
	1.3	71	2	219
	5.0	87	0	28
S5	0	56	53	510
	1.3	109	28	385
	5.0	120	56	293
S6	0	85	264	907
	1.3	159	121	46
	5.0	276	0	9
S7	0	58	152	580
	1.3	62	8	9
	5.0	51	0	6
X11	0	23	101	873
	1.3	106	6	24
	5.0	482	5	85
X32	0	0	40	475
	1.3	131	0	4
	5.0	104	0	4
X22	0	8	121	528
	1.3	106	20	144
	5.0	172	0	115
X23	0	21	76	442
	1.3	121	15	27
	5.0	49	0	34

tional and the other as exclusively discriminative.

The results of Experiment 3 suggest that in the single reversal paradigm, what is learned is the same regardless of which stimulus is held constant across sessions and which is assigned an explicit discriminative role. In other words, the two training procedures are interchangeable. If this is indeed the case, then it should be possible during training to switch from one of these training procedures to the other with no decrement in performance. This hypothesis was tested in Experiment 4.

EXPERIMENT 4

Method

Subjects and apparatus. The subjects in Experiment 4 were the members of Group 2 in Experiment 3. The apparatus was the same as that used in the preceding experiments.

Procedure. On the day after their generaliza-

tion test in extinction, the subjects were returned for retraining under their Phase 2 training condition. The HL was present on all trials; the S+ was red and the S- was blue. All but 1 subject, S5, quickly resumed good performance. This subject was eliminated and the others trained for six sessions. On the next day the subjects experienced the first of three consecutive sessions of training in which the key was illuminated by the red keylight on all trials; S+ was HL and S- was HL. Trial and blackout durations were the same as in the preceding experiments.

Results and Discussion

Table 3 presents the discrimination ratio (i.e., percentage of total responses emitted to S+) for each subject for each of the 3 days immediately preceding the switch in training conditions and each of the 3 days subsequent to the switch. Clearly the subjects' performance was not asymptotic at the time of the

GROUP 1

Fig. 5. Group mean bidimensional generalization gradients along wavelength and houselight intensity dimensions for subjects in Group 1 of Experiment 3. Note that for these subjects the key color had been the explicit discriminative cue during single reversal training.

GROUP 2

Fig. 6. Group mean bidimensional generalization gradients along wavelength and houselight intensity dimensions for subjects in Group 2 of Experiment 3. Note that for these subjects the houselight intensity had been the explicit discriminative cue during single reversal training.

switch. Note, however, that not a single subject showed any decrement at the time the procedures were switched and all continued their improvement.

GENERAL DISCUSSION

What does this consistent pattern of results tell us about the nature of conditional discrimination learning in the single reversal paradigm? The notion of a hierarchical stimulus relationship central to the conceptual definition of a conditional discrimination by Sidman (1986) and others can be salvaged only if the relationship is thought to be symmetrical, that is, if each stimulus is said to be conditional upon the other. By this conception the subjects learn parallel rules (e.g., “if HL, then blue” and “if blue, then HL”). Although this interpretation is quite different from the unidirectional hierarchical relationship Sidman (1986) and others have described, it is tenable and consistent with our data. The problem with it is that it is unclear what sort of evidence could disconfirm such an interpretation. It is therefore more parsimonious to adopt a view that Carter and Werner (1978) called the “configuration” model. According to this conception, the subjects learn which combinations of cues

signal reinforcement or nonreinforcement and they respond accordingly. Whether or not the combinations form psychological units or Gestalts is not relevant for present purposes, although evidence reviewed earlier suggests that such a process would retard the learning of a conditional discrimination rather than support it. Note that the distinction between conditional and discriminative stimulus functions is problematical in any paradigm (including that used in the classical study by Lashley, 1938)

Table 3
Discrimination ratios for subjects in Experiment 4.

Subject	Days preceding training switch			Days following change to alternate training procedure		
	3	2	1	1	2	3
X34	81.1	94.8	95.8	97.8	97.0	99.7
S6	90.8	98.6	99.4	100	100	100
S7	99.2	99.7	100	100	100	100
X11	95.6	99.0	99.5	99.6	100	99.7
X32	81.2	95.8	90.0	97.6	100	100
X22	98.5	97.1	97.3	100	100	100
X23	N/A ^a	91.9	93.9	100	100	99.8

^a N/A refers to data not available due to equipment malfunction.

in which the putative conditional and discriminative cues are presented simultaneously.

Of course not all conditional discrimination training procedures used simultaneous presentation. When Cumming and Berryman (1965) wrote of a conditional cue as a "selector of discriminations" that provides "instructional control" to the subject, they had in mind the matching-to-sample paradigm in which sample (i.e., conditional) and comparison (i.e., discriminative) cues are presented sequentially. In a variant of this procedure called symbolic matching (see Rodewald, 1973) sample and comparison stimuli from different dimensions (e.g., line angles and colors) can be used. This makes it possible to test for symmetry in conditional relations (e.g., will subjects who have learned to match a blue sample with a vertical line comparison stimulus select a blue comparison stimulus when presented with a vertical line sample?). Thus far the results of such studies with animals have been largely negative (see D'Amato, Salmon, Loukas, & Tomie, 1985; Sidman et al., 1982); thus the distinction between conditional and discriminative stimulus functions seems to be viable in analyzing such tasks.

In the single reversal procedure used in the present experiments there were two values of the putative conditional stimulus, each paired with the two values of the explicit discriminative cue with two combinations signaling reinforcement and two signaling extinction. Not all conditional discrimination paradigms are of this sort, however. For example, in feature-positive or feature-negative discriminations the conditional cue is paired with only one of the two discriminative cues (see Jenkins & Sainsbury, 1969). Indeed in one paradigm, rather than determining which discriminative cue is S+ and which is S-, the conditional cue determines whether or not a discrimination contingency is in effect (see Chase & Heinemann, 1972; Heinemann & Chase, 1970). There is but one feature that all conditional discrimination paradigms have in common and it is this feature that should provide the basis for a definition. Conditional discriminations are those in which combinations of stimuli, rather than stimulus elements, signal reinforcement contingencies. This seems preferable to Sidman's (1986) conceptual definition in terms of hierarchical stimulus relationships because it is in the behaviorist tradition of

functional definitions, it is universally applicable, and because the presence or absence of hierarchical relationships is often incapable of empirical verification.

REFERENCES

- Boneau, C. A., & Honig, W. K. (1964). Opposed generalization gradients based upon conditional discrimination training. *Journal of Experimental Psychology*, **68**, 89-93.
- Carter, D. E., & Werner, T. J. (1978). Complex learning and information processing by pigeons: A critical analysis. *Journal of the Experimental Analysis of Behavior*, **29**, 565-601.
- Chase, S., & Heinemann, E. G. (1972). Choice based on redundant information: An analysis of two-dimensional stimulus control. *Journal of Experimental Psychology*, **92**, 161-175.
- Cumming, W. W., & Berryman, R. (1965). The complex discriminated operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stimulus generalization* (pp. 284-330). Stanford, CA: Stanford University Press.
- D'Amato, M. R., Salmon, D. P., Loukas, E., & Tomie, A. (1985). Symmetry and transitivity of conditional relations in monkeys (*Cebus apella*) and pigeons (*Columba livia*). *Journal of the Experimental Analysis of Behavior*, **44**, 35-47.
- Heinemann, E. G., & Chase, S. (1970). Conditional stimulus control. *Journal of Experimental Psychology*, **84**, 187-197.
- Jenkins, H. M., & Sainsbury, R. S. (1969). The development of stimulus control through differential reinforcement. In N. J. Mackintosh & W. K. Honig (Eds.), *Fundamental issues in associative learning* (pp. 123-161). Halifax, Nova Scotia: Dalhousie University Press.
- Lashley, K. S. (1938). Conditional reactions in the rat. *Journal of Psychology*, **6**, 311-324.
- Riccio, D. C., Urda, M., & Thomas, D. R. (1966). Stimulus control in pigeons based on proprioceptive stimuli from floor inclination. *Science*, **153**, 434-436.
- Richards, R. W. (1979). Stimulus control following training on a conditional discrimination. *Animal Learning & Behavior*, **7**, 309-312.
- Rodewald, H. K. (1973). Application of Bower's one-element model to paired-associate learning by pigeons. *Journal of the Experimental Analysis of Behavior*, **19**, 219-223.
- Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213-245). Hillsdale, NJ: Erlbaum.
- Sidman, M., Razin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, **37**, 23-44.
- Thomas, D. R. (1985). Contextual stimulus control of operant responding in pigeons. In P. D. Balsam & A. Tomie (Eds.), *Context and learning* (pp. 295-321). Hillsdale, NJ: Erlbaum.
- Thomas, D. R., Curran, P. J., & Russell, R. J. (1988).

- Factors affecting conditional discrimination learning by pigeons: II. Physical and temporal characteristics of stimuli. *Animal Learning & Behavior*, **16**, 468-476.
- Thomas, D. R., & Goldberg, H. (1985). Conditional discrimination learning by pigeons: The role of training paradigms. *Bulletin of the Psychonomic Society*, **23**, 256-258.
- Thomas, D. R., McKelvie, A. R., & Mah, W. L. (1985). Context as a conditional cue in operant discrimination reversal learning. *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 317-330.
- Thomas, D. R., McKelvie, A. R., Ranney, J., & Moye, T. B. (1981). Interference in pigeons' long-term memory viewed as a retrieval problem. *Animal Learning & Behavior*, **9**, 581-586.
- Thomas, D. R., Stengel, T., Sherman, L., & Woodford, M. (1987). Factors affecting the learning and performance of a conditional discrimination by pigeons. *Journal of the Experimental Analysis of Behavior*, **48**, 277-287.

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