SOME DISCRIMINATIVE PROPERTIES OF FIXED RATIO PERFORMANCE IN THE PIGEON¹

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The discriminative control over a spatial choice response exercised by prior behavior was studied using a procedure involving discrete exposures to a two-member chained schedule. The initial member (red key) was either a smaller or larger fixed ratio (Mix FR:FR), the completion of which produced, after a 1-sec delay, two white response keys. If the larger FR had been completed as the initial chain member, a single peck on the right white key was reinforced; after the smaller FR, a peck on the left white key was reinforced. Frequencies of unreinforced responses (S^A responses) were determined with several pairs of red-key FRs: 95-5, 75-25, 65-35, 60-40, 58-42 and 50-50. The S^A response frequencies were low through the FR pair 65-35; sharp increases were obtained with pairs 60-40 and 58-42. Later, curves analogous to stimulus generalization functions were obtained using a probe procedure. Finally, the delay interval between completion of a red-key FR and the white-key choice response was manipulated: results were variable, but S^A response frequencies tended to increase with increasing delays.

Behavioral control has been defined (Ferster and Skinner, 1957, p. 725) as "an observed tendency for a probability or rate of responding to vary with the presence and absence of a variable (e.g., a stimulus)." The basic operation in establishing control by a stimulus is to relate systematically differential reinforcement to stimulus differences. Differential reinforcement involving extinction defines the S^D - S^A relation in which the operant ideally occurs in the presence of S^D and not in the presence of S^A (Skinner, 1938). Differential reinforcement involving schedules of reinforcement systematically related to stimulus differences defines the multiple schedule (Ferster and Skinner, 1957). Since the operant often occurs with substantial frequency in the presence of the several stimuli in the multiple schedule, stimulus control is inferred from an immediate

change in the pattern or temporal distribution of responses when the stimuli are changed. While differential reinforcement involving extinction may be considered a special case of the multiple schedule, the term exemplifying stimulus control, S^D or discriminative stimulus, has been formally defined only in that special case. Casual usage has extended the meaning to differential reinforcement in multiple schedules which do not involve extinction as one of the components as well as those which do.

A recent experiment by Terrace (1963a) has markedly extended knowledge of stimulus control. He established differential stimulus control by two stimuli with a procedure involving neither differential reinforcement according to schedule (the multiple schedule procedure) nor differential reinforcement involving extinction (the S^D - S^A procedure). Further, he has shown that the peak shift (Hanson, 1959) does not occur with his procedure for establishing differential control (Terrace, 1964) and that the "negative stimulus" in his procedure has different properties with respect to some drug effects (chlorpromazine, imipramine) than does an S^A established through extinction (Terrace, 1963b). Current usage of the concept of stimulus control outdates the formal definition based exclusively upon the S^D - S^A experiment. Recent work such as that

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of Terrace implies that a modern statement of the principle of stimulus control should identify several subclasses or types of controlling stimuli with properties at least partially distinctive to each subclass.

The present experiment was concerned with the kinds of events which exert stimulus control over behavior. Typically, the events with which differential reinforcement has been correlated are environmental events which can be specified physically, *e.g.*, light waves, sound waves, changes in temperature, *etc.* Since behavior also can be specified physically, differential reinforcement can be systematically related to behavioral differences just as it may be related to stimulus differences. The organism's own behavior replaces the stimulus term in a stimulus control paradigm, and a specified operant comes under the control of the organism's behavior occurring before that operant rather than a stimulus event in the usual sense of the word "stimulus". Since the substitution of the prior behavior for the stimulus term leaves unchanged the logical relations among terms in the experimental paradigm, it is convenient to speak of the prior behavior as exercising stimulus control and as having discriminative properties. It has been traditional to speak of a proprioceptive stimulus in the same context, although procedures for directly measuring proprioceptive stimuli are lacking. Further, the behavioral manipulation of a proprioceptive stimulus always proceeds by way of the prior behavior, suggesting that the concept is superfluous in an operational analysis of behavior.

The present experiments were concerned with the discriminative properties of FR performances. An experimental paradigm designed to study stimulus control was adapted by substituting FR performances for the stimulus terms.

METHOD

Subjects

Three male Carneaux pigeons, each of which had a varied experimental history, were reduced to 75 to 80% of free-feeding weight and maintained there throughout the experiment. A daily experimental session terminated after 60 reinforcements except as noted below. The reinforcer was a 3-4 sec access to mixed grain.

Apparatus

The experimental box was a standard pigeon chamber. Two Gerbrands response keys were mounted symmetrically above the grain hopper 2.5 in. apart, center to center, and 8.5 in. above the floor of the box. Automatic programming equipment was employed, and the recording equipment consisted of a cumulative response recorder and electromagnetic impulse counters.

Procedure

The schedule of reinforcement on which the performances of the three birds were stabilized before introducing the experimental variables consisted of discrete-trial exposures to a two-member chained schedule. The initial member of the chain was either a larger or smaller FR (Mix FR:FR) programmed on a response key transilluminated with red light (red key). The red key alternated left-right position from trial to trial, but the sequence of larger and smaller FRs was unsystematic and unrelated to red-key alternation. Every 32 trials consisted of 16 of each of the two FRs. Completion of an FR darkened the red key, and both response keys were transilluminated with white light (white keys) after 1 sec of no responding. If the larger (smaller) FR had been completed, a single response on the right (left) white key produced reinforcement followed by a 15-sec intertrial interval. A response on the left (right) white key produced only the intertrial interval. A noncorrection procedure was employed, *i.e.*, the red-key FR selector advanced on a white-key response rather than a reinforcement.

The schedule of reinforcement was approximated more and more closely by a sequence of steps in a preliminary procedure. The earlier steps in the preliminary procedure established the chained schedule in its final form with the exception of the terminal chain member: a single white key followed completion of an FR requirement on the red key. The single white key appeared on the left if the smaller FR (FR 25) had been completed on the red key and on the right if the larger one (FR 75) had been completed on the red key. A peck on the white key produced reinforcement which was followed by the 15-sec intertrial interval. The single white key in the terminal chain member was replaced by two white keys during

the final step of the preliminary procedure. Both keys were transilluminated with white light, but a resistor was placed in series with the previously dark (now, S^A) key, *i.e.*, the right key after FR 25 and the left key after FR 75. Over several sessions, the series resistance was reduced, thereby increasing the brightness of the S^A key. A response on the less bright (S^A) key was followed immediately by the 15-sec intertrial interval. Few such responses occurred. Eventually the white keys attained brightness equality with an average frequency of S^A responses for each bird of about 10% or less. The procedure for transferring discriminative control from the brightness difference in the terminal chain member to the FRs in the initial chain member is an example of "fading" (Terrace, 1963c; Moore and Gol-diamond, 1964).

The experiments proper involved manipulating (a) the red-key FRs in the initial chain member and (b) a delay interpolated between the two chain members. Each of those variables was manipulated in more than one way.

1. Manipulation of the discriminative FRs.

(a) *Stabilization at each FR pair: Birds R28 and B434.*

The red-key FRs were set at FR 95 and FR 5. When a stable frequency of S^A responses, *i.e.*, unreinforced responses on the white keys, was attained, the FRs were changed to FR 75 and FR 25. In succession, frequencies of S^A responses were determined at the FR pairs 65-35, 60-40, 58-42, and 50-50. Each pair sums to 100 responses, so that the average work requirement in the initial chain member was constant over the several values of the independent variable. Since the final pair (50-50) could not exercise discriminative control over the choice response, either white key was designated as the S^A key on 50% of the trials in an arbitrary sequence.

(b) *Probe procedures: Birds R28, B433, and B434.*

i. Birds R28 and B434 were restabilized on an FR pair of FR 95 and FR 5 in the initial chain member. Data were collected employing two types of probe procedure, each of which involved probe FRs between FR 95 and FR 5. With the larger FR maintained at 95 responses, the smaller one was changed for a single trial on each of 12 randomly placed trials during a session. Probes were never employed on consecutive trials. The animal's

white-key response, after completing the probe FR, was recorded, and the smaller FR was immediately returned to FR 5. Probe values of 7, 10, 20, and 40 responses were employed, and the 12 probe trials in a session were arranged in three blocks, each composed of the four probe values in an unsystematic order. Three probe sessions were completed with about six standard sessions (FR 95 and FR 5 throughout) between successive probe sessions.

The second type of probe session was similar except that the smaller FR was maintained at FR 5, and the larger was changed to values of 75, 50, 25, and 10 responses.

ii. In addition to the above probe procedures, we probed with values larger than the large FR and smaller than the small. Birds R28 and B433 were restabilized on an FR pair of FR 75 and FR 25 in the initial chain member. Probe sessions were run as above. With R28, the probe values were FRs of 1, 4, 9, and 18 responses, each substituted for the smaller of the baseline pair. Probe values of 100, 150, 250, and 450 responses, each substituted for the larger of the baseline pair, were used with B433.

2. Manipulation of the delay between the discriminative FRs and the choice response.

The procedures described above employed a delay of 1 sec between the chain members. The following procedures were designed to manipulate the delay systematically and to determine its effects on the frequency of S^A responses. In all of the following procedures, the red-key FRs were maintained at FR 75 and FR 25.

(a) *Stabilization at each delay value: Birds R28, B434, and B433.*

The three birds were stabilized at a delay value of 1 sec between chain members. Frequencies of S^A responses were then determined at delay values of 3, 5, 7, and 9 sec (successively) for birds R28 and B434 and at delay values of 2, 4, 8, and 16 sec (successively) for B433.

(b) *All delay values within a single session: Bird B433.*

The session of 60 reinforcements was divided into four blocks of 15 reinforcements each. A different delay value was programmed for the 15 consecutive reinforcements of each block. The delays studied were 1, 4, 8, and 16 sec, and the sequence of delay values within the session was unsystematic. Three such ses-

sions were completed, each with a different sequence (Session 1: 1, 16, 4, 8 sec; Session 2: 8, 4, 16, 1 sec; Session 3: 16, 8, 1, 4 sec). No more than one such session was run per week, and the intervening daily sessions consisted of 60 reinforcements at the 1-sec delay value.

RESULTS

Figure 1 consists of six cumulative records for bird R28. Each record shows Mix FR:FR performance on the red key at one of the FR pairs used. In all of the records, a reinforced choice response is indicated by a "pip" on the record following reset of the pen. Mixed schedule performance was obtained. An important feature of those records is the non-differential pausing before beginning the larger and smaller FRs. Other effects characteristic of mixed FR:FR schedules (Ferster and Skinner, 1957) may be seen. The segment of record 95-5 marked "a" shows an effect which has been called "priming". A short pause after reinforcement was followed by a number of responses approximately equal to the smaller FR. When those responses did not darken the red key and thereby complete a smaller FR requirement, a second pause occurred. The second pause was longer than the first and may be considered appropriate to the larger FR requirement. Overall, the record for the FR pair 95-5 often shows uneven per-

formance at the start of the larger FR. An exception appears at b. The subsequent records in Fig. 1 show that as the larger and smaller FRs of a pair became more nearly equal, the uneven performance at the start of the larger one was replaced by an inflection in response rate when a number of responses approximating the smaller FR had been emitted (c, d, e). An inflection in response rate is evident in each of the FR 50 performances shown in the record labeled 50-50. The performances obtained from the other birds differed in no important respect from those shown for R28.

1. Manipulation of the discriminative fixed ratios.

(a) Stabilization at each FR pair.

Figure 2 shows data obtained with birds B434 and R28. The ordinate is % S^A responses (% S^AR). That statistic is based on the total number of white-key responses per session of 60 reinforcements. The abscissa represents the larger FR of a pair; each FR pair summed to 100 responses. Each point plotted is the median of the last five sessions under the experimental condition, and the vertical bar through a point shows the range of scores over the five sessions.

The points plotted at the FR pair 50-50 are connected by a dotted line because they represent a control condition in which the FRs were equal and could not develop discriminative control. S^A responses were made on approximately 50% of the trials. The pigeons did not respond randomly, however, even though reinforcement for responses to the left

Fig. 1. Sample performances on the red-key, Mix FR:FR for bird R28. Fixed ratio sizes for the several FR pairs appear to the right of each record. A "pip" after an FR record indicates a reinforced choice response. Performances of the other birds were essentially the same. The details in the records at a, b, c, d, e are discussed in the text.

Fig. 2. The results of the experiment in which FR size was manipulated. The ordinate shows % S^A responses (% S^AR); the abscissa, the size of the larger FR in each pair. The FRs of each pair summed to 100 responses. Each point is a median based on the last five sessions with the pair, and the vertical bar through each point shows the range of scores over those five sessions.

and right white keys was programmed unsystematically over trials. R28 developed a tendency to respond predominantly to the left white key. B434 developed a similar pattern after showing the more complicated "strategy" of choosing the white key on the other side from which the red-key FR had been completed. The 50-50 points for both birds are based on incomplete sessions (fewer than 60 reinforcements), since long pausing on the red key often developed, and sessions were terminated to run other birds. An indication of increased pausing is apparent in the cumulative record for R28 (Fig. 1, record 50-50).

To the degree that control over the choice response was maintained by the discriminative FRs, % S_{AR} should fall below 50%. The remaining points for both birds are at the FR pairs 95-5, 75-25, 65-35, 60-40, 58-42. Those points are connected with a solid line and imply good discriminative control through the pair 65-35. % S_{AR} increased sharply for both birds to values between 20 and 30% for the pair 60-40. B434 showed a further increase in % S_{AR} at the pair 58-42, while little change from the former value was shown by R28. Incomplete sessions were run by B434 at the 58-42 pair. In general, the curves in Fig. 2 for the two birds are strikingly similar. The pair 58-42 continued to maintain discriminative control over the choice response as evidenced by the 65% (B434) and 70% (R28) frequencies of reinforced choice responses. Following the nondiscriminative pair 50-50, both birds were returned directly to the pair 75-25. Discriminative control was completely re-established, without the aid of fading procedures, after about six sessions for B434 and 10 sessions for R28. The final % S_{AR} scores, 8% for B434 and 9% for R28, are represented by the secondary points at 75 on the abscissa.

(b) *Probe Procedures.*

The results of the probe procedures in which intermediate FR sizes were substituted during a single trial for either the larger or smaller members of the baseline 95-5 pair are shown in the upper two panels of Fig. 3. The upper panel is for bird R28 and the middle, bird B434. The sizes of the probe FRs are shown on the abscissa; the ordinate shows the frequency (maximum, nine) with which a bird responded to the right white key after the larger FR (FR 95) of the baseline pair had been replaced by a probe (solid-line graphs)

and also the frequency (maximum, nine) with which a bird responded to the left white key after the smaller (FR 5) of the baseline pair had been replaced by a probe (dotted-line graphs). The probe trial, white-key responses just specified are labeled "same", inasmuch as they are the white-key responses controlled by the baseline FRs. The larger vertical bars on the abscissa at 95 and 5 mark the baseline FRs.

Both birds responded in essentially the same fashion with respect to the probes inserted for the larger FR. A probe FR of 75 responses was always followed by a response on the right white key; a probe FR of 10 responses was never followed by a response on the right white key in the case of B434 and once in the case of R28. The intermediate probes, FR 50 and FR 25, produced intermediate frequencies of "same" or right white-key responses. The probes inserted for the smaller FR of the base-

Fig. 3. The results of the probe procedures in which probe FRs intermediate between the baseline 95-5 pair were examined (top two panels) and in which probes larger and smaller than the baseline 75-25 pair were examined (bottom panel). The ordinates show the frequency (maximum, nine) with which the birds responded to the probe as though it were the original FR. Probe sizes are marked on the abscissas. Top two panels: the solid lines show the data obtained when the larger FR was changed; the dashed lines, when the smaller was changed.

line pair produced different curves for the two birds. B434 showed a rather steep curve in which the FR 40 probe was never followed by a response on the left white key; the FR 20 probe was followed by a left white-key response seven out of nine times, and FR 7 and FR 10 probes were always followed by responses on the left white key. Bird R28 showed a flatter curve than did B434, primarily as a result of six out of nine responses on the left white key on trials in which the FR 40 probe was programmed.

The results of the probe trials with probes larger and smaller than the larger and smaller FRs (FR 75 and FR 25) of the baseline pair are shown in the bottom panel of Fig. 3. Again, the ordinate refers to the frequency (maximum, nine) with which the birds responded "same" to a probe FR. A "same" response is defined as a response on the right white key following a probe larger than FR 75 and a response on the left white key following a probe smaller than FR 25. The abscissa shows the sizes of the several probes, and the difference in scale to the left and right of the two larger vertical lines (which mark the baseline FR pair) should be noted. The outstanding characteristic of the two curves are the degrees to which all of the probes smaller than FR 25 control responses on the left white key and all of the probes larger than FR 75 control responses on the right white key. The two curves are essentially flat.

2. Manipulation of the delay between the discriminative FRs and the white-key responses.

(a) *Stabilization at each delay value.*

The data obtained are summarized in Fig. 4, panels A, B, and C. The ordinate shows % S^AR, and the abscissa represents the length of the delay in seconds. The vertical bar through a point shows the range of scores over the last five sessions which were used to determine the median.

The graphs shown in Fig. 4 are similar to the degree that each depicts an increase in % S^AR with increases in the delay between completion of a red-key FR and transillumination of the white-keys. There is, however, little uniformity among the several graphs with respect to precise shape. B434 showed a rise in % S^AR up to a delay of 5 sec with no real change in performance at delays of 5, 7, and 9 sec. R28, on the other hand, showed no change

Fig. 4. The results of the experiment in which the delay between completion of a discriminative FR and the choice response was manipulated. The ordinates are % S^AR responses (% S^AR); the abscissas, delay in seconds. The points plotted in panels A, B, and C are medians for the last five sessions at each delay; the vertical bars through those points, the ranges of scores over the last five sessions. Panel D shows the results of programming four different delays within the same session (see text).

in performance over delays of 1, 3, and 5 sec with an increase in % S^AR to about 20% at delays of 7 and 9 sec. Because of the different curves generated by the two birds, a third bird was run using the same procedure but with delays of 1, 2, 4, 8, and 16 sec. The results are shown in panel C of Fig. 4. Overall, the curve gives the impression of a smoothly rising function, although, perhaps, there is no real difference from 1- to 4- or even 8-sec delays with a genuine increase in % S^AR at a delay of 16 sec. Unfortunately, the curve just described for B433 differs from either of the curves in panels A and B.

(b) *All delays within a single session.*

Panel D of Fig. 4 presents the data obtained with B433 in the procedure which programmed several delays (1, 4, 8, and 16 sec) within a single session. The resulting graph shows a small rise in % S^AR from the 1- to the 4-sec delay. There is a substantial rise at 8 sec. The % S^AR score at 16 sec is essentially the same as that shown at 8 sec. In general, the graph suggests a two-valued function, somewhat like the one obtained with R28 (panel B).

DISCUSSION

Although he was avowedly concerned with "symbolic processes" and "kinesthetic stimuli", Hunter's (1920) classic work with the temporal maze was one of the earliest experimental programs to deal with the discriminative properties of behavior. Appropriate performance at the choice point of a temporal maze required that the animal's behavior be controlled by the direction(s) of its previous turn(s) at that choice point. Current laboratory methods are more sophisticated and analytic than those available to Hunter, and re-examination of his problem area with modern experimental techniques should yield significant results. The procedure, which is both general and objective, for such a re-examination was stated above: an experimental situation is arranged so that the organism's prior behavior substitutes for the stimulus term in a paradigm designed to study stimulus control. The feasibility of the experimental program is demonstrated in at least a preliminary way by the results of the present research, in addition to a recent experimental report by Rilling and McDiarmid (1965). They employed a procedure very similar to ours, but with the initial chain member programmed on the center key of a three-key pigeon chamber. The response requirement in their initial chain member was an FR of 50 responses or one of fewer than 50 (Mix FR:FR). The latter FR was varied as the experimental variable. Completion of the response requirement on the center key darkened it and transilluminated two side keys. If the bird had pecked the center key 50 times to complete the initial chain member, a single peck on the right side key was reinforced while a peck on the left side key "darkened the box and delayed reinforcement for 60 sec." If the response requirement on the center key was fewer than 50 responses, the reinforcement contingencies on the side keys were reversed. There were a number of procedural differences between theirs and the present experiment, making it difficult to compare in detail the two sets of findings. Broadly speaking, however, they established excellent discriminative control over the choice response in the terminal chain member. Further, they obtained an effect which they called "response bias", *i.e.*, a tendency for the bird to favor one of the choice

keys as the number of responses differentiating the two FRs in the initial chain member decreased. We obtained a similar effect, discussed below in connection with the often noted maximizing tendency obtained in a probability matching situation. Finally, Rilling and McDiarmid obtained better discriminative control over the choice response than we did; they report a % S^ΔR value of about 10% with a discriminative FR pair of 50 responses and 35 responses, a difference of 15 responses. Our pair consisting of 58 and 42 responses, a difference of 16 responses, produced a % S^ΔR score of about 30%.

The difference cannot be easily reconciled because of the many procedural differences between the two experiments.

The use of FRs as the discriminated behavior, as in the present experiments, provides precise experimental control over response output but introduces other variables confounded with FR size. A larger FR requires more time to complete, and it is possible that elapsed time from the first to the last response of an FR was an important source of discriminative control. Discriminative control over responding by elapsed time has been demonstrated by Reynolds and Catania (1961). On the other hand, if a bird should develop different terminal response rates for FRs of different sizes, the different terminal rates could serve differentially to control subsequent behaviors. The terminal response rate in an FR performance has an advantage over other sources of control by being a relatively discrete event (compared with the entire FR performance) quite proximal to the behavior under discriminative control. Thus, the question as to precisely which dimension of the FR performances on the red key provided the discriminative control over the choice response cannot easily be answered. Fixed ratio size was manipulated as it is usually manipulated in the conditioning laboratory, and we are content at this point to speak in terms of that operation, rather than to infer a dimension of behavior which was "really" responsible for the discriminative control. It is not difficult, however, to design suitable experiments for the purpose of isolating and evaluating the several dimensions of FR performance (or any other performance, for that matter) with respect to discriminative properties.

Figure 2 shows that discriminative control over the choice response was for both birds essentially unimpaired through the FR pair 65-35. A sharp increase in % S^AR was obtained with the next pair studied (60-40), and that result suggests that some "critical" point was reached at which discriminative control by the FRs was attenuated and replaced partially by some other source of control over the choice response. The nature of that alternative source of control is suggested by the performance of the birds on the nondiscriminative (50-50) pair. We have commented on the development of systematic choice patterns with respect to the white keys under the nondiscriminative experimental condition. Both birds eventually chose the left white key almost exclusively. It is noteworthy that the white keys in the nondiscriminative condition constituted a probability matching program (noncorrection procedure) with a spatial problem. The papers by Bullock and Bitterman (1962) and by Graf, Bullock, and Bitterman (1964) reported maximizing in that situation, and the present performances agree with that finding. The tendency to maximize (preceded by a systematic choice pattern) was probably the source of control over the choice response which competed with the discriminative control exercised by the red-key FRs under the 60-40 and 58-42 conditions. A consideration of the experiments just cited suggests that the shape of the functions in Fig. 2 might have been modified had a correction procedure been used. This would have guaranteed an equal number of reinforcements on the two white keys, since the same discriminative FR would have been programmed on the red key until it was followed by a reinforced white-key choice response. Responding exclusively on only one of the white keys is discouraged in that a correction procedure forces a shift to the alternative white key after an unreinforced white-key choice. The noncorrection procedure that was used permitted the bird to obtain all of its reinforcements by consistently choosing one of the white keys, albeit the reinforcements were obtained on a 50% partial reinforcement schedule. Had a correction procedure been used, the sharp break at the 60-40 pair might have been replaced by a somewhat more gentle rise in % S^AR in connection, perhaps, with a lower S^AR frequency at the 60-40 and 58-42 pairs.

When a stimulus gains control over behavior, that control is shared by similar stimuli. Experiments in stimulus generalization (e.g., Guttman and Kalish, 1956; Hearst, Koresko, and Poppen, 1964) often plot response rate (or some derivative) as the dependent variable. The choice response in the present experiments precluded a response rate measure. The probe procedures were designed to provide information regarding generalized control employing the two-valued dependent variable. The results agree with the assumption that FR sizes intermediate between the larger and smaller of the baseline pair generated intermediate probabilities of response to either of the white keys. That result is analogous to the graded-rate functions obtained in the usual stimulus generalization experiment. When probes larger than the large and smaller than the small FR were examined, flat curves were obtained. (Evidently, larger than "large" is still large and smaller than "small" is still small.) If one considers the baseline FR 25 an S^D for a response to the left white key and the baseline FR 75 an S^A for a response to the left white key, then probes smaller than FR 25 are analogous to generalization test stimuli on the side of an S^D opposite an S^A. Similar considerations, with a reversal in the S^D and S^A functions of the baseline FRs, apply to a right white key response in relation to the probes larger than FR 75. It is known that the relative symmetry of a generalization gradient is altered by discrimination training, so that the gradient is raised for stimuli on the side of an S^D opposite an S^A. That effect has been obtained by Sloane (1964) who used response rate as the dependent variable and by Hoffman and Fleshler (1964) who graphed a conditioned suppression ratio as the dependent variable.

The present experiments employed a discrimination procedure, and the flat, *i.e.*, raised, gradients obtained with test FRs smaller than FR 25 and larger than FR 75 agree, therefore, with previous data on generalization processes. But for ceiling effects, peak shifts also might have been detected.

Perhaps the most curious aspect of the present research concerns the results obtained by manipulating the delay interpolated between completion of a discriminative FR and the white-key response. It is reasonable to conclude from panels A, B, and C of Fig. 4 that % S^AR

increased with increasing delay intervals, but the nonuniformity of the three curves is evident. A possible interpretation of the nonuniformity is suggested by panel D which shows the results obtained when several delays were sampled within the single session. Good discriminative control was maintained at delays of 1 and 4 sec with poorer control at delays of 8 and 16 sec. The two-valued nature of that graph, in conjunction with the spatial nature of the choice response, suggests that the birds were making a "choice response" immediately after completing the discriminative FR and then "waiting" for the white keys. Munn (1950) has summarized early observations on the development of orienting responses in delayed reaction experiments. If bird B433 were able to "wait" or stand in place for at least 4 sec but not for as long as 8 sec, then the curve obtained in panel D of Fig. 4 could be expected. The discrepancies among the four curves might reflect differences in the degrees to which each bird developed a mediating orienting response, and it is also likely that that behavior varied from time to time for the individual bird. The spatial choice response is, therefore, a particularly poor method for studying delayed stimulus control ("memory"). A better procedure would seem to involve a stimulus choice rather than a spatial choice. Blough (1959), however, has reported a dramatic example of how pigeons developed behavioral chains that mediated correct choices in a delayed matching to sample experiment involving a stimulus choice.

As a final consideration, we suggest that procedures which substitute behavior for the stimulus term in a paradigm designed to study stimulus control, particularly in the special paradigms denominated psychophysical methods, could serve to answer some interesting questions regarding FR schedules. Because the stimulus properties of behavior have been relatively neglected in the conditioning laboratory, there is little information with which to formulate answers to questions such as:

1. Does Weber's law apply, even approximately, to FR performance? Is a just-detectable increment in FR size a constant fraction of the FR to be increased? If so, how does the postreinforcement pause on an FR schedule relate to FR size expressed in just-detectable increments?

2. Given an FR of N responses, how large an FR is "subjectively" half as large; twice as large, etc.?

REFERENCES

- Blough, D. S. Delayed matching in the pigeon. *J. exp. Anal. Behav.*, 1959, 2, 151-160.
- Bullock, D. H. and Bitterman, M. E. Probability matching in the pigeon. *Amer. J. Psychol.*, 1962, 75, 634-639.
- Ferster, C. B. and Skinner, B. F. *Schedules of Reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Graf, V., Bullock, D. H., and Bitterman, M. E. Further experiments on probability-matching in the pigeon. *J. exp. Anal. Behav.*, 1964, 7, 151-157.
- Guttman, N. and Kalish, H. I. Discriminability and stimulus generalization. *J. exp. Psychol.*, 1956, 51, 79-88.
- Hanson, H. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, 58, 321-334.
- Hearst, E., Koresko, M. B., and Poppen, R. Stimulus generalization and the response-reinforcement contingency. *J. exp. Anal. Behav.*, 1964, 7, 369-380.
- Hoffman, H. S. and Fleshler, M. Stimulus aspects of aversive control: stimulus generalization of conditioned suppression following discrimination training. *J. exp. Anal. Behav.*, 1964, 7, 233-239.
- Hunter, W. S. The temporal maze and kinaesthetic sensory processes in the white rat. *Psychobiol.*, 1920, 2, 1-18.
- Moore, R. and Goldiamond, I. Errorless establishment of visual discrimination using fading procedures. *J. exp. Anal. Behav.*, 1964, 7, 269-272.
- Munn, N. *Handbook of Psychological Research on the Rat*. New York: Houghton Mifflin, 1950.
- Reynolds, G. S. and Catania, A. C. Temporal discrimination in pigeons. *Science*, 1961, 135, 314-315.
- Rilling, M. and McDiarmid, C. Signal detection in fixed-ratio schedules. *Science*, 1965, 148, 526-527.
- Skinner, B. F. *The Behavior of Organisms. An Experimental Analysis*. New York: Appleton-Century-Crofts, 1938.
- Sloane, N. H., Jr. Stimulus generalization along a light flicker rate continuum after discrimination training with several S's. *J. exp. Anal. Behav.*, 1964, 7, 217-222.
- Terrace, H. S. Discrimination learning with and without errors. *J. exp. Anal. Behav.*, 1963a, 6, 1-27.
- Terrace, H. S. Errorless discrimination learning in the pigeon: effects of chlorpromazine and imipramine. *Science*, 1963b, 140, 318-319.
- Terrace, H. S. Errorless transfer of a discrimination across two continua. *J. exp. Anal. Behav.*, 1963c, 6, 223-232.
- Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. *Science*, 1964, 144, 78-80.