AN OPERANT DISCRIMINATION TASK ALLOWING VARIABILITY OF REINFORCED RESPONSE PATTERNING[1]

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Five pigeons were trained to perform a discrimination task allowing variability of reinforced response patterning. The task consisted of moving a stimulus light within an 4 × 4 matrix of lights from the top left position to the bottom right position by pecking on two keys in succession in order to obtain a reinforcement. A peck on one key moved the light one position to the right and a peck on the other key moved it one position down. After preliminary training on alternating fixed-ratio 3 schedules of reinforcement, the birds could peck on either key in any order, but more than three responses on a key resulted in a blackout followed by the return of the stimulus light to the start position. Results indicate that initially the birds used a wide variety of response patterns to obtain reinforcement, but with continued practice, response patterns became more stereotyped.

Continuous exposure to a particular schedule of reinforcement has been found to decrease the variability of response forms (Muenzinger, 1928; Skinner, 1938; Notterman, 1959; Antonitis, 1951). These studies were concerned with the topography of the individual instrumental motor "response". Muenzinger's study involved the part of the body used by guinea pigs in solving a puzzle box problem; Skinner's observations and Notterman's systematic description concern the force and duration of lever presses by rats; and Antonitis' study involved horizontal position of nose-thrusting responses of rats. In contrast with these results concerning variability of parameters of a single motor "response", the present study is concerned with variability of response patterning in a discriminative operant schedule in which many related but discrete patterns of responses are reinforced.

METHOD

Subjects

Five adult male Palmetto White Carneaux pigeons were maintained at approximately 80% of their free-feeding weight. All had previous experience with differential-reinforcement-of-low-rate (DRL) schedules of food reinforcement.

Apparatus

The experimental chamber was enclosed in an ice chest. A white noise generator and a ventilation fan provided masking noise. Two translucent plastic response keys were mounted 20 cm (8 in.) above the floor (behind 2-cm (0.75-in.) diameter holes through one wall of the chamber), 10 cm (4 in.) apart on either side of a 6 cm (2.25 in.) square array of stimulus lights (see Figure 1). When the keys were transilluminated by a white light, a force exceeding 0.015 N applied to the key broke an electrical contact that operated control and recording circuits. The keys were disconnected from the control circuitry when darkened. The square array of stimulus lights was made up of four rows of four 1-cm (0.5 in.) diameter translucent plastic capped lights. Fifteen of the caps were yellow, and the sixteenth cap in the lower right corner of the array was red. The control circuit allowed only one stimulus light to be illuminated at a time. The reinforcing event was a 2-sec presentation of mixed grain, which was accessible through a 5-cm (2-in.) square opening 7 cm (2.75 in.) below the stimulus lights. When grain was presented, the keys were darkened, the houselight went off and the feeder opening was illuminated. The houselight, the stimulus light, the keylights,

and the feeder light were the only sources of illumination in the chamber. A television camera permitted observation of the behavior.

Procedure

The birds did not require preliminary key training because of their previous conditioning history with DRL schedules. The shaping procedure consisted of three stages. In the first stage, none of the stimulus lights was lit. In succession, one, two, and finally three responses (fixed-ratio 3) on either of the illuminated keys were required to obtain reinforcement. Pecks on the preferred key were then not reinforced until the birds were reliably satisfying the FR 3 requirement on the non-preferred key. In the last two stages, at the start of a trial, the top-left yellow simulus light was illuminated. During a trial period, a response on the key to the right of the stimulus array (the "right key") stepped the stimulus light to the right unless the lit stimulus light was one of the four lights in the right column. Similarly, responses on the key to the left of the stimulus light (the "down key") moved the lit position one row down unless the lit stimulus light was in the lowest row. The second stage required at least three responses on both keys in any sequence moving the lit position to the red "goal light" to produce food, but more than three responses on either key did not change the position of the lit stimulus light ("running off the board" was not possible). The final stage had the requirement of exactly three responses on each of the keys in any sequence to produce food—a fourth response

on either key during a single trial "ran the stimulus light off the board" and produced a total blackout for 2 sec (as the houselight and stimulus lights were off) instead of reinforcement. This was defined as an incorrect trial; subsequently, the stimulus light was turned on in the start position for a new trial. Three responses on each key moved the cue light to the goal and resulted in the lighting of the lower-right red-capped stimulus light (the goal light) for 2 sec. While the goal light was lit, the pigeons had access to food with the hopper light on and the house- and keylights off (key pecks during this period could not produce a blackout). This was defined as a correct trial. All response patterns were recorded with a Sodeco Printer.

Each session terminated automatically after 100 trials. Sessions were conducted daily with a few exceptions. Ten to 40 sessions were required for the individual subjects to attain stable baselines above 80% correct. For three of the pigeons, the baseline was maintained for 50 to 90 sessions after the 80% baseline was achieved to study changes in patterns of responding. Two of the pigeons served as controls with regard to the importance of the stimulus lights as cues. After maintaining a baseline accuracy better than 90% correct for 30 and 36 sessions, all stimulus lights were off while all other parameters of the schedule remained constant. Birds 25 and 26 were chosen for this "lights off" condition because in the early sessions they were consistently emitting a higher proportion of correct responses. After 39 sessions, the cue lights were reinstated for the final 24 sessions.
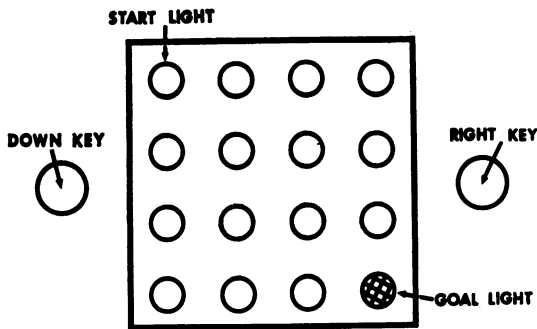

Fig. 1. Diagram of the stimulus panel. A peck on the right key moved the lit position one column to the right and a peck on the down key moved the lit position one row down. Moving the lit position from the upper left position to the lower right (goal) position produced access to food. More than three responses on a key resulted in a blackout.

RESULTS

Figure 2 represents the changes in percentage of reinforced trials per session for all five pigeons. The percentage of reinforced trials of the pigeons that were always provided with stimulus light cues (P21, P22, P24) is shown in Part A; Part B shows the performance of the two cue-light controls (P25, P26). Within 10 to 40 sessions, all five pigeons were emitting correct response sequences in more than 80% of the trials. The numbered sessions do not include the first two preliminary stages of shaping, which took between two to five sessions for the individual pigeons. Their pattern at the end of this period consisted of three

to six responses on one key followed by three on the other. Within the first session of the final schedule (allowing "running off the board"), all pigeons adopted a variable mode of responding that tended to light the central, rather than the peripheral, cue lights. It might be noted that these patterns of responding with more than one key switch are less efficient in terms of motor output and that the one-switch pattern (*i.e.*, three responses on one key followed by three on the other key) was the dominant pattern that the birds returned to with continued training. The preferred (modal) pat-

terns at the end of the experiment can be represented as sequences of r and d for right key and down key; they were rrrddd for two birds (P24 and P26) and dddrrr for three birds (P21, P22, and P25).

Figure 3 illustrates the changes in pattern frequency distribution during the experiment by showing a frequency histogram for the patterns used by P24 for a two-day period at the outset (Sessions 4 and 5, filled bars) compared to a final two-day period (Sessions 102 and 103, unfilled bars). The 50 possible patterns of responding for a single trial are arbitrarily num-
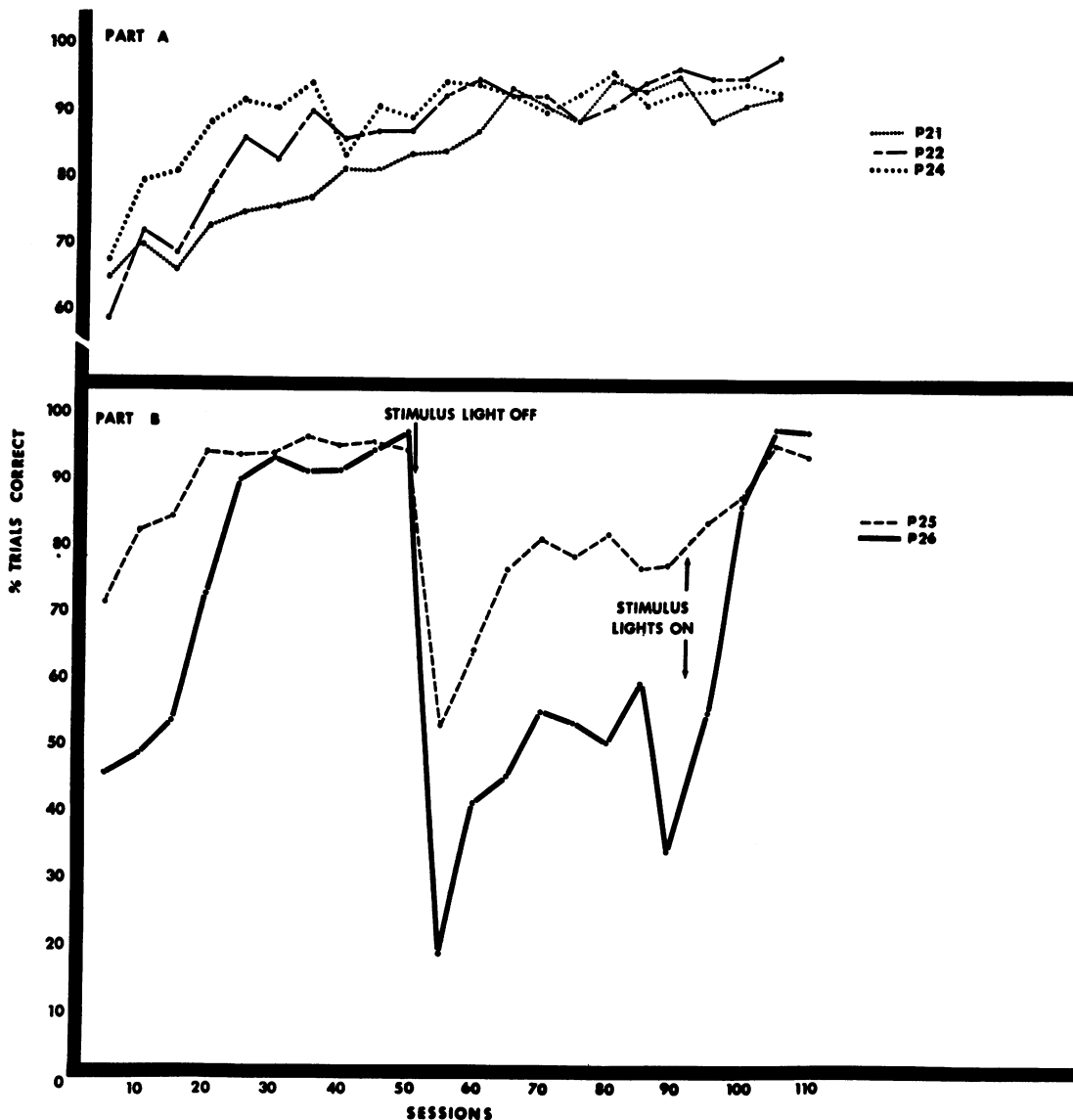

Fig. 2. Mean per cent correct trials as a function of training sessions. Each point represents the mean for five sessions. Part A: constant stimulus conditions (P21, P22, P24). Part B: cue light control (P25, P26).

bered 1 to 50 on the nominal abscissa; the corresponding ordinate represents frequency of pattern occurrence as percentage of total trials during the sessions indicated. Patterns 1 through 20 represent the 20 possible correct response patterns; patterns 21 through 50 represent the 30 unreinforced possibilities. In the early sessions, more patterns were used while in later sessions one correct pattern dominated.

This decrease in variability of response patterns for all five subjects is presented graphically in Figure 4. During the first two weeks of training, the mean number of correct patterns used per session was approximately 16 of a possible 20. After 100 sessions, the group of three pigeons not exposed to a cueless control period had a mean use of three patterns per session of the 20 possible correct patterns.

Both control pigeons showed dramatic decreases in accuracy when cue lights were not illuminated (see Figure 2B). P25 decreased 70 points in percentage accuracy from 97% with cue light to 27% without, while P26 made the maximum decrease of 100% between two days. The performance of both subjects partially recovered within 20 days to new baselines (80% for P25, 50% for P26). When the stimulus lights were returned, the improvement in performance was much less rapid than its previous disruption. Approximately 10 sessions were required by both pigeons before a 90 to 100% criterion was regained. Figure 4 shows that pattern variability increased significantly both with the removal of cue lights and their reinstatement, and that these control birds never regain the degree of stereotypy typical of the birds that had the cue light throughout the 110 sessions.

DISCUSSION

The decrease in "response" variability with continued reinforcement supports previous findings by Muenzinger (1928), Skinner (1938), Notterman (1959), and Antonitis (1951), and extends the applicability of their conclusions
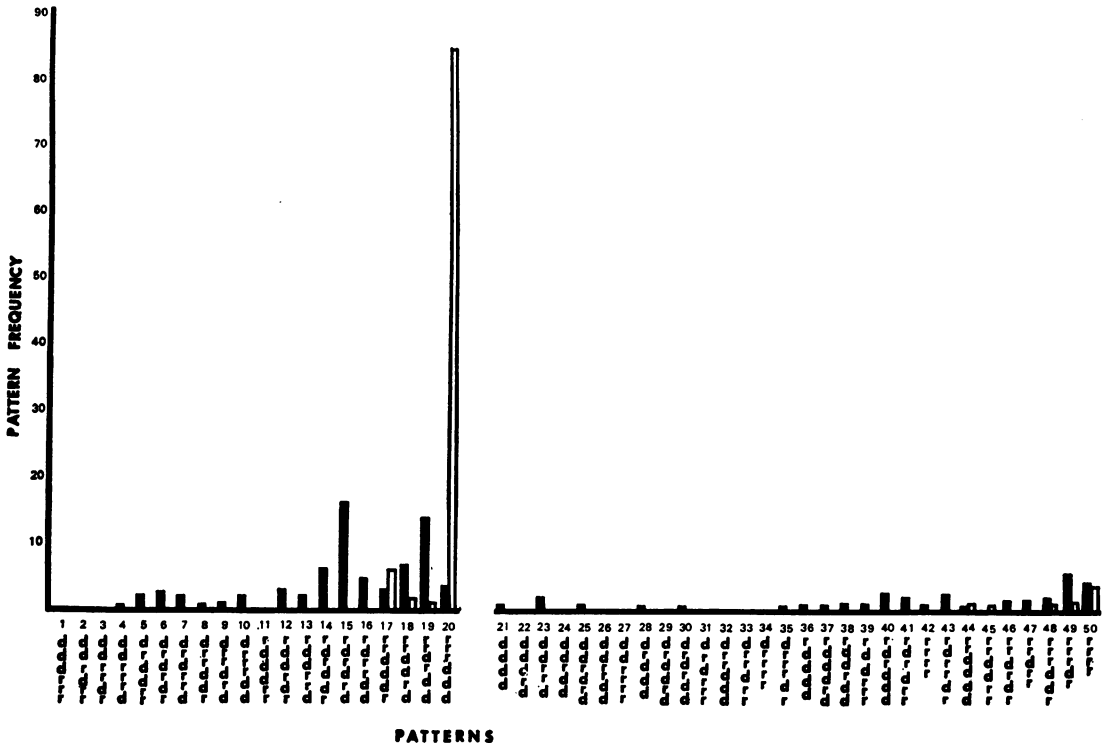

Fig. 3. Changes in pattern frequency distribution during the experiment. Frequency histogram for the patterns used by P24 for a two-day period at the beginning of training (Sessions 4 and 5; filled bars) compared to a final two-day period (Sessions 102 and 103; unfilled bars). Patterns 1 through 20 were reinforced, 21 through 50 were not reinforced. The columns of letters below each pattern number indicate the sequence of right (r) and down (d) responses in that pattern.
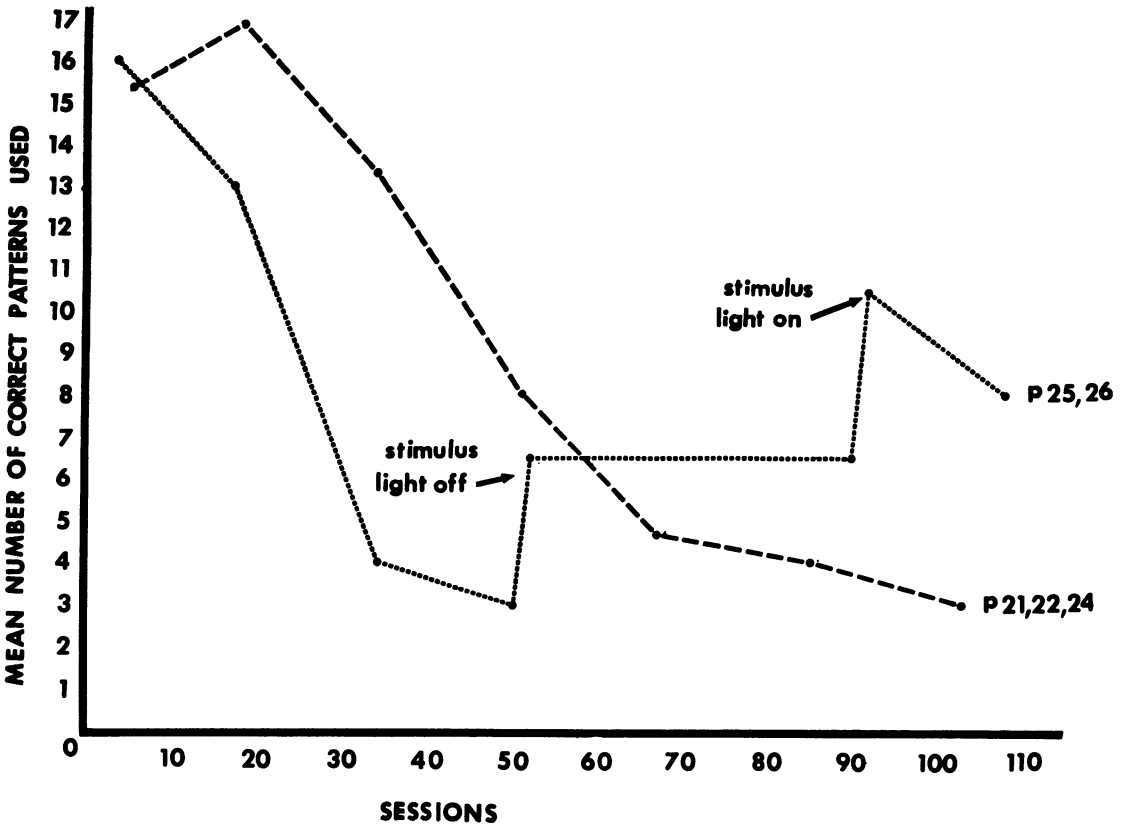
Fig. 4. Changes in mean number of correct patterns used per session during the course of the experiment. Each point represents a two-session mean for each of the two experimental groups: (1) the two pigeons subjected to a cueless control period (P25, P26) and (2) the three pigeons subjected to constant stimulus conditions (P21, P22, P24).

concerning parameters of the single motor response to serial patterns of responding. In the previous studies on response variability, "trial" topography was relatively limited in that a single response was required for reinforcement and the variability studied was in physical parameters of the single response. In the present study, the physical parameters (*i.e.*, force, locus, duration) of the key pecks would be expected to become progressively stereotyped with continued training, but these were not measured. The concern here was with the additional variability of the patterns of sequences of two discrete responses.

From the initial training of the birds one could have expected a predominant pattern, the alternating FR 3, to be maintained, once the birds were allowed to "run off the board". The behavior of all four birds, however, changed dramatically during this phase of training in that a great variety of patterns were

used. This variable response pattern may be understood better if one examines the consequences of running off the board. In this case, more than three responses made by the birds on any one key is followed by the blackout of the experimental chamber; therefore, one would expect the birds to reduce the number of consecutive responses emitted, *i.e.*, to switch keys more frequently. Examination of the data reveals that this was indeed the case. A "centralizing" tendency in response patterns occurred with the simple alternation emerging as the modal pattern. As the birds eliminated errors, they slowly returned to the previous predominant and perhaps most efficient method of obtaining reinforcement, the alternating FR 3 pattern.

The "freedom of choice" in response patterning in the present paradigm is considerable and can be increased (or decreased) by changing the size of the matrix of stimulus lights. It

is perhaps remarkable that the pigeons exercised this freedom to such a large extent, and that even after 10,000 trials the pattern of responding was far from completely stereotyped.

The initial disruption of performance in the removal of stimulus light control indicates that the cue lights were the discriminative stimuli maintaining the behavior. This is also supported by our observations over closed-circuit television that the birds made frequent observing responses between pecks when cue lights were available. The performance of both control pigeons only partially recovered with continued practice in the absence of the cue lights. The stimulus control of this cueless performance is not clear but perhaps is related to counting paradigms wherein a specific number of responses on one lever followed by a single response on another lever produces reinforcement (cf. Mechner, 1958; Mechner and Guevrekian, 1962). It is perhaps significant that in the final 24 sessions with the cue lights reinstated, these birds did not develop the degree of stereotypy typical of their pre-control period and that of the birds that had the cue lights throughout the experiment (see Figure 4), suggesting that behavior acquired in the absence of cue lights may permanently reduce stereotypy. The control birds during these final sessions were at least as accurate as the others (see Figure 2); thus, stereotypy is not necessary for success.

The results of previous workers (Muenzinger, 1928; Skinner, 1938; Notterman, 1959; Antonitis, 1951) have shown that variability of response topography decreases with continued training. The present results extend this conclusion to serial patterns of responding: continued practice decreases variability of trial topography. The success of the pigeons with this task also suggests that an extension of the paradigm might be useful as an interspecific comparative test of problem-solving ability.

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