

BEHAVIORS OBSERVED DURING S- IN A SIMPLE DISCRIMINATION LEARNING TASK¹

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Key pecking of pigeons was reinforced with food in the presence of a horizontal line and never reinforced in the presence of a vertical line. Highly stereotyped behaviors, as well as key pecking, were observed and recorded in the presence of both stimuli. Results showed that a high proportion of time spent in the presence of the horizontal line was occupied by key pecking, a high proportion of time in the presence of the vertical line was occupied by stereotyped nonkey-pecking behaviors, and intermediate proportions of time spent in the presence of intermediate stimuli were occupied by each class of behavior during generalization tests. Similar running rates (number of key pecks divided by observed key-pecking time) were obtained in the presence of all stimuli, indicating that changes in time rather than tempo accounted for the changes in overall rates of key pecking. An exception occurred in responding to the horizontal line as differential performance was developing. In addition to an increase in time spent key pecking, increased running rates occurred in seven of eight birds, suggesting that both time allocation and tempo play a role in behavioral contrast of overall rates of key pecking.

Key words: discrimination, generalization, behavioral contrast, timeout, interim activities, time allocation, key peck, pigeons

In a simple discrimination learning paradigm, an organism is presented with two stimuli: one is positively correlated with reinforcement (S+) and the other is negatively correlated with reinforcement (S-). Traditionally, the behavior of interest in discrimination studies has been the response that is established in the presence of the S+ and which is an explicit part of the reinforcement contingency. For example, in a study by Jenkins and Harrison (1960), the criterion for a discrimination was met when the rate of pigeons' key pecking to S+ was "at least four times greater" than the rate to S-. Thus, differential responding is, in this case, conceptualized as the existence of different strengths of responses where strength is reflected in some dimension, such as rate of occurrence of a discrete event.

An alternative to conceptualizing differential responding as different rates of a single measured response is to consider those differ-

ent rates as indicating different probabilities that a single class of responses will be selected from all the other behaviors in the repertoire of an organism. A lower rate of responding in the presence of S- might be viewed, then, as an increase in occurrence of behaviors other than the response conditioned to S+. Although this approach is not new (*e.g.*, Guthrie, 1935), it has recently been revived by Schoenfeld and Farmer (1970). They proposed that since "behavior is a continuous stream", what is changed by reinforcement procedures is not the tempo of a discrete response but rather the frequency of occurrence of one behavior relative to all others.

The present investigation explored three areas of concern.

1. If the organism is conceived to be "always doing something", what kinds of behaviors are observed when the organism is not engaged in the explicitly conditioned response? Observing the direction and magnitude of movement on a joystick by human subjects, Terrace (1974) recorded active S- responding that was antagonistic to the S+ response.

Staddon and Simmelhag (1971) demonstrated that highly stereotyped behaviors of

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pigeons (*e.g.*, turning around in the chamber) increase in frequency of occurrence during periods of low probability of reinforcement. Employing similar techniques, the first objective of the present study was to observe and record the behaviors of pigeons in a discrimination learning task where key pecking in the presence of S+ was reinforced according to a variable-interval (VI) schedule and where key pecking in the presence of the S- was never reinforced. To facilitate a direct comparison of topographically different behaviors, it was necessary to record time spent engaging in key pecking and other behaviors. The hypothesis was that, as the time allocated to key pecking decreased in the presence of S-, time occupied by highly stereotyped behaviors would increase.

2. A related issue concerns the nature of these stereotyped behaviors. In describing the behavior of pigeons during the S- periods, Terrace (1966) noted that "it has been regularly observed that following discrimination learning with errors, S- evokes various emotional responses such as wing flapping and turning away from the key." The three photographs provided to illustrate such "emotional responses" (Terrace, 1966, p. 317) show that the head of the animal was facing in some direction away from the key containing the visual stimulus. Such observations suggest that the birds may have been engaging in behaviors that served to remove the S-.

Terrace (1971) and Rilling, Kramer, and Richards (1973) have, in fact, demonstrated that following discrimination training with errors, a pigeon will learn to peck another key, the only consequence of which is to turn off the S- for a brief period of time. The parallel between responses labelled by Terrace as "emotional responses" and the timeout response is further illustrated by a decrease in each type of behavior with extended discrimination training (Terrace, 1971, 1972; Rilling, Askew, Ahlskog, and Kramer, 1969). These studies and observations suggest the possibility that in conventional discrimination procedures in which localized visual stimuli are employed, the animal learns some response that removes the S- from view, whether or not a response manipulandum (*e.g.*, a timeout key) is provided. To explore this possibility, behaviors that served to remove a visual stimulus were observed and recorded. Two

classes of behaviors that could produce such an effect included: (a) certain head positions and/or locations in the chamber or (b) a time-out key peck that turned off the illumination behind the stimulus display.

3. The third issue relates to the tempo of key pecking. Are the different overall S+ and S- key-pecking rates attributable to an underlying shift in the tempo with which the pigeon strikes the key, or are they a function of different amounts of time spent engaging in a constant tempo of key pecking relative to time spent engaging in other behaviors? The latter choice is supported by Blough (1963) and Schaub (1967), who found that changes in overall rates during extinction and discrimination training, respectively, reflected changes in the long interresponse-time (IRT) class, rather than a shift in the IRT distribution as a whole.

In the present study, obtaining a temporal measure of the proportion of stimulus intervals occupied by key pecking permitted an analysis of rates of key pecking at a more molecular level than is typically afforded by the single manipulandum procedure. A running-rate measure was computed by dividing the total number of key pecks to each stimulus by the total times in which the pigeon was observed to engage in this response. Running rates in the presence of the two training stimuli (S+ and S-) and in the presence of five generalization test stimuli with values intermediate to S+ and S- were examined to assess if different stimuli affected only the proportions of the characteristic S+ and S- behavior or if they affected specific properties of these behaviors.

METHOD

Description of the experimental procedure is separated into two major sections: I. Apparatus and Methodology with respect to subjects, and II. Apparatus and Methodology with respect to the observer.

I. APPARATUS AND METHODOLOGY (SUBJECT)

Subjects

Eight experimentally naive male White Carneaux pigeons, 5 to 6 yr of age, were maintained at approximately 80% of their free-feeding weights throughout the experiment.

Water was available at all times in their home cages.

Apparatus

Experimental chamber. The experimental chamber was a 46.64-cm cubic box made of 1.27-cm plywood painted uniformly flat black. For viewing purposes, the top of the chamber was a plate of 0.63-cm thick glass. Two circular response keys, 3.81 cm in diameter, were located on the discriminanda wall 20.32 cm from the floor of the chamber. The main key was positioned in the center of this wall and a timeout key was located 7.62 cm to the left of the main key. This timeout key was covered with black electrical tape for one experimental group. Both keys required approximately 0.22 N of force to be operated. All key pecks were recorded automatically by standard electromechanical equipment. Reinforcement consisted of grain made available automatically by a Lehigh Valley Electronics Grain dispenser for 3 sec, through a 1.90-cm square opening located in the floor of the chamber directly below the main response key. Extraneous sounds were masked by a speaker delivering white noise within the chamber. There was no houselight.

Stimuli. The stimuli were various orientations of a 1.1- by 3.4-cm black opaque tape superimposed on a white background. A horizontal line (0 degrees) served as the S+ and a vertical line (90 degrees) served as the S-. Test orientations included 0, 15, 30, 45, 60, 75, and 90 degrees rotation around the center of the stimulus exposure. All discriminative stimuli and test stimuli were changed manually.

The stimuli were located at a distance of 3.8 cm directly behind the main response key and were mounted in Kodak Gelatin Filter Frames. The exposed surface of the entire display was 6.02 cm in diameter. A 15-W light located 1.27 cm behind the stimulus transilluminated the stimulus display.

The back of the timeout key was covered with green acetate film and white vellum, producing an unsaturated green light. The timeout key was transilluminated by a 7-W light located directly behind the key. This key remained on throughout the session.

Experimental Design and Procedure

Experimental groups. The eight subjects were assigned to one of two groups. Group I

($n = 4$) had access to the main key but not to the timeout key, which was covered with black electrical tape. Group II ($n = 4$) had access to both keys.

Preliminary training. On the first day, main-key pecking was shaped in the presence of the S+. Each peck was reinforced on a continuous reinforcement schedule (CRF). After the key peck had been established, a 12-sec blackout period was introduced, which served to separate the 60-sec stimulus-on periods and to permit the experimenter to change the stimuli during subsequent discrimination training and generalization testing. When this blackout was in effect, the main-key light went dark, no responses were recorded, and reinforcement was unavailable.

During this first session, the timeout key was illuminated for Group II. A single peck on this key produced a 10-sec timeout in which the main key was dark and pecks on either key had no effect. The timer controlling the stimulus-on periods was unaffected by the timeout responses, to ensure the independence of the timeout responses and the scheduled presentations of the discriminative stimuli. Sessions 2 through 10 involved a gradual reduction in the frequency of reinforcement from CRF to a variable-interval 45-sec schedule (VI 45-sec).

S+ only training. After the 10 days of preliminary training, the schedule of reinforcement was further reduced to VI 60-sec. S+ only training was continued for 25 days. Session length during this baseline was 24 stimulus-on periods.

Discrimination training. Discrimination training consisted of equal presentations of S+ (0-degree line) correlated with VI 60-sec and S- (90-degree line) correlated with extinction. The stimuli were randomly alternated with the stipulation that neither the S+ nor the S- appear for more than three consecutive periods. Each stimulus was presented for 12 of the 24 periods per session. Discrimination training continued for 10 days.

Generalization testing. Following a warm-up phase, during which each training stimulus was presented for three periods and each was correlated with the appropriate training condition, generalization testing was introduced. Seven test stimuli were employed: 90-, 75-, 60-, 45-, 30-, 15-, and 0-degree angular orientations of the line superimposed on the white back-

ground. All stimuli were correlated with extinction and were presented once within each of four blocks. The stimulus-on period was 60 sec. To minimize the effects of testing under extinction, a retraining phase was administered between each successive block; this phase consisted of presentations of both S+ and S- with their appropriate training conditions. The length of the test session was 28 stimulus-on periods. Nine such tests were administered, tests being separated by five sessions of discrimination training. The order of stimulus presentation was counterbalanced across all test sessions.

II. APPARATUS AND METHODOLOGY (OBSERVER)

Observational Apparatus

Figure 1 presents a schematic diagram of the characteristics and location of the observational equipment in relation to the experimental chamber. All observed behaviors were recorded via levers and push buttons operated by the same observer (JFR) throughout the experiment. The observed behaviors, as well as the automatically recorded key-peck responses, were recorded on an Esterline Angus 20-channel Multiple Event Recorder. In addition, three observed response classes (described below) were recorded by timing devices and counters.

Observed Response Description

On the basis of observations made during the preliminary training phase, the following responses classes were identified for each bird:

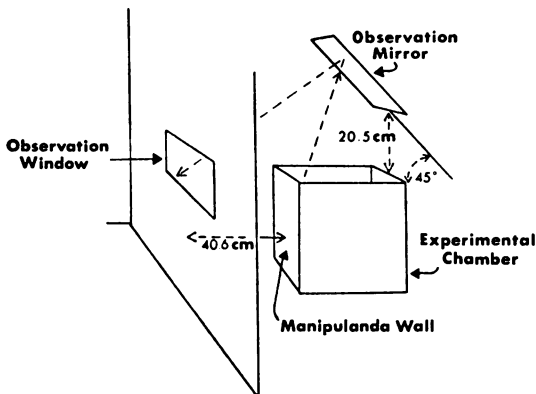


Fig. 1. Schematic diagram of experimental apparatus illustrating spatial relationship between animal chamber and observational equipment.

1. *Key-pecking behaviors.* Continuous head movements directed at the main key was the defining characteristic of this class of behaviors. Due to the difficulty of tracking each discrete key peck, this class of behaviors was recorded continuously, *i.e.*, the appropriate lever was depressed throughout a burst of discrete key pecks. The lever was released when the head of the bird turned away from the key or the pecking motion stopped. In addition, behaviors of the bird could qualify for this category of response even if actual contact between the bird's beak and the glass key was not of sufficient force to operate the key micro-switch.

2. *Interim behaviors.* The defining characteristic of this response class was any regularly occurring behavior pattern other than key-pecking behavior. Due to equipment limitations, durations of only one such activity could be recorded within any one experimental session. Staddon and Simmelhag (1971) presented a classification of observed activities of pigeons in a similar experimental environment, and for the sake of continuity their terminology is maintained in this paper. This response class is discussed in greater detail in the results section.

3. *General timeout behaviors.* This category refers to a class of behaviors that served to remove the visual stimulus from view.

The major source of illumination in the chamber was the stimulus lamp located behind the discriminative stimuli. This fact, coupled with the flat black surface of the experimental chamber, produced clearly defined shadows both within the chamber and on the surface of the bird itself.² This sharp shadow gradient (illustrated in Figure 2) provided an unambiguous measure of this general timeout response class, which was defined as any behavior that resulted in *both* eyes of the bird being located in the areas of low illumination.

The fact that the interim behaviors and the general timeout behaviors are not necessarily incompatible response classes deserves further elaboration. The following situations illustrate different degrees of relatedness that could conceivably exist between the two categories of behaviors. The bird could engage in an interim activity in which (a) *all* portions of that

²The timeout key did not substantially alter these lighting conditions.

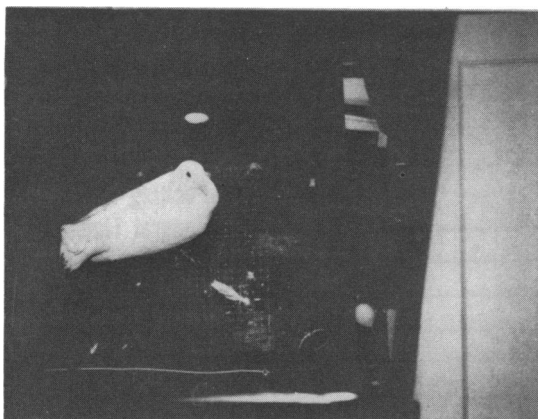


Fig. 2a. Photograph of the observational mirror (see Figure 1) reflecting the interior of the experimental chamber. The camera angle was the same as the angle of observation used in the experiment. Overhead lighting has been added for purposes of illustration. The timeout key has been covered.

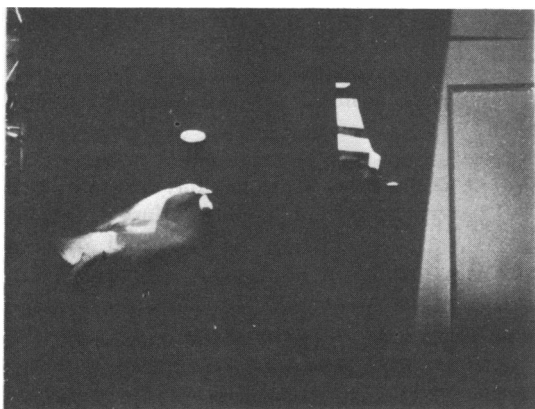


Fig. 2b. Photograph taken from the same angle as Figure 2a with the overhead lighting omitted. It illustrates the sharply contrasted levels of illumination on the surface of the bird. The stimulus lamp that illuminates the main key was increased to 100 W for photographic purposes but the resultant picture approximates very closely the actual experimental conditions in regard to sharpness of the shadow gradient. It should be noted that the head position of this bird does not qualify for the general timeout behavior class, since both eyes are not within the areas of low illumination.

behavior also qualify for the general timeout category, *e.g.*, head in magazine opening, head movements in either the left- or right-front corners of the chamber; (b) *no* portion of which could qualify for the general timeout class, *e.g.*, backing away from, but still facing the main key; and (c) only *some* portions of which could qualify for the general timeout response class, *e.g.*, when turning a full circle,

only when the bird faced the rear wall would both eyes be out of the area directly illuminated by the stimulus lamp.

Recording Techniques

The three major observed response classes (key pecking, interim behaviors, and general timeout behaviors) were recorded continuously, *i.e.*, the appropriate lever was depressed throughout the duration of the response. The three levers operated timing devices, so that at the end of the session the total amount of time occupied by each behavior was available. Other behaviors that did not qualify for any of the three major categories were also recorded via push buttons. In addition to all observed behaviors, main-key pecks, timeout-key pecks, reinforcement, and programmed stimulus changes were recorded on the Esterline Angus Multiple Record. Figure 3 provides an illustrative sample of the permanent record.

RESULTS

Reliability of Recording Key Pecking

To assess the reliability of the observed key peck, an analysis of the Esterline Angus Multiple Record (Figure 3) was conducted by sampling both subject and observer key-peck responses at intervals of 7.5 sec (marked by vertical lines) throughout an entire session. A 2×2 contingency table (presence *versus* absence of subject and observer response) was then tabulated. Such analysis was performed on all birds on three separate experimental conditions: (1) last day of S+ only training, (2) the sixteenth day of discrimination training, and (3) the fifth generalization test. The Phi coefficients were 0.88, 0.97, and 0.95, respectively, indicating a high degree of relatedness between observer and subject key-pecking responses.

Preliminary Training

As the frequency of reinforcement was decreased from CRF to VI 15-sec during preliminary training, interim behaviors and general timeout behaviors began to appear immediately after food was presented. With further reductions in the schedule, these behaviors were also observed between bursts of key pecking. No timeout-key pecks occurred for any subject in Group II during this phase of the

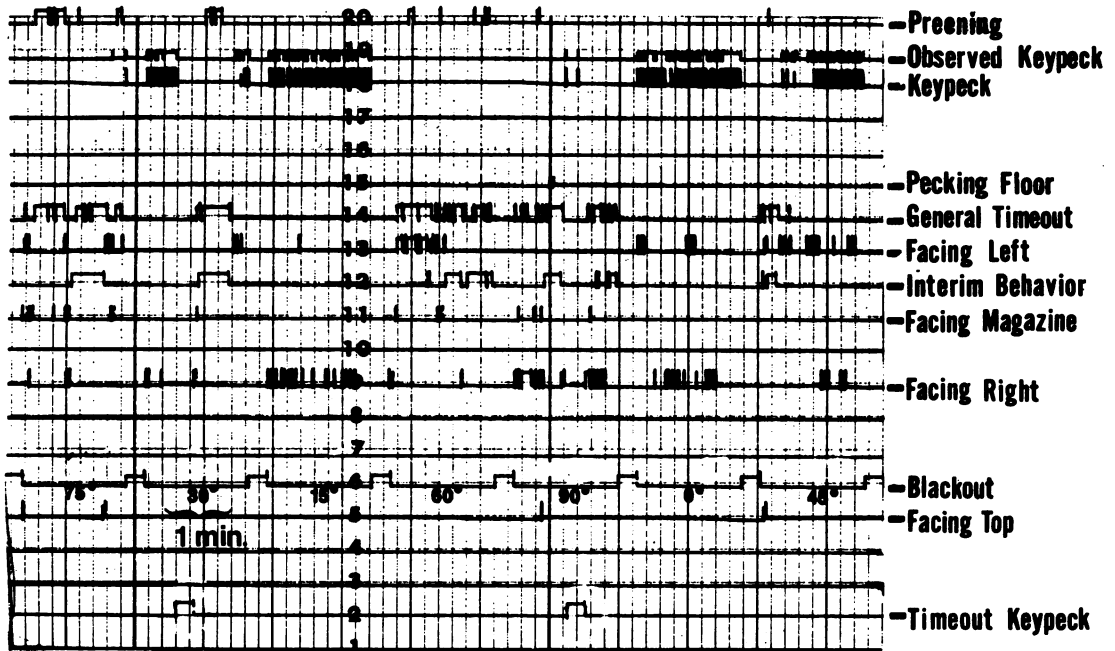


Fig. 3. Sample of Esterline-Angus multiple record. Response classes and experimenter-programmed events are noted at right. This sample was taken from the second generalization test of Bird 101. The test stimuli are noted immediately below line 6.

experiment. The observed behaviors were similar to those behaviors described by Staddon and Simmelhag (1971), suggesting the possibility that they were controlled by stimuli associated with low probabilities of reinforcement and would, therefore, be likely candidates for the behaviors that would be observed during S— in subsequent discrimination training. Thus, a decision was made to select the most regularly occurring behavior that followed reinforcement as the recorded interim behavior. For the most part, this decision was not difficult, as there was usually one predominant mode of behavior for each bird. Table 1 presents a description of observed activities, those behaviors selected as the interim behavior, and other frequently observed behaviors which also qualified for the general timeout response class.

S+ Only Training

The proportions of the total stimulus-on periods occupied by each of the three classes of behavior during the S+ only training sessions are plotted in Figure 4.

As mentioned earlier, the possibility existed that the bird could engage in an interim behavior in which all portions, no portions, or

only some portions of that behavior could also qualify for the general timeout class of behavior. It was found that the observed interim behaviors for all birds had at least some components that also met the criterion for the general timeout response class. Therefore, the obtained durations of the general timeout category were the sum of (a) portions of the interim activity and (b) other behaviors (*e.g.*, preening, head in extreme corner of the chamber, *etc.*). Of the four birds in Group II, only 102 and 103 pecked the timeout key during S+ only training, three and 17 times, respectively.

Discrimination Training

Overall key-peck response rates, obtained during discrimination training, and a running-rate measure (computed by dividing the total number of key pecks by the observed duration of key pecking) are presented in Figure 5. The proportions of the S+ and S— stimulus-on periods occupied by the three observed response classes and the timeout-key peck responses are plotted in Figure 6.

Five of the eight birds exhibited considerable difficulty in acquiring the line-tilt discrimination. Thus, after 15 days of discrimination

Table 1

Response Number	Name	Description of Observed Activities ¹
R ₁	Magazine wall	Any response in which the bird's head and body are oriented toward the magazine wall.
R ₃	Pecking floor	Any pecking movements directed toward floor.
R ₄	Turning around in chamber	Responses in which the body of the bird is oriented more than 90 degrees away from the magazine wall.
R ₅	Flapping wings	Vigorous movements of bird's wings.
R ₈	Pacing movements along walls of chamber	Side-stepping movements from left to right with breastbone close to the walls of the experimental chamber. Often accompanied by (a) beak pointed toward top of chamber, (b) wing flapping, (c) hopping.
R ₉	Preening	Movements in which the beak makes contact with the feathers on the bird's body.
R ₁₁	Head in magazine	Head movements in the immediate vicinity of magazine opening.
R ₁₇	Roosting	Bird "squats down". Absence of mobility.
R ₁₈	Facing right	Movements in which head and/or body of bird orient toward right side of chamber, <i>i.e.</i> , from right side of main key to 90 degrees away from key.
R ₁₉	Facing left	Movements in which head and/or body of bird orient toward left side of chamber, <i>i.e.</i> , from left side of main key to 90 degrees away from key.

Observed Behaviors for Each Subject²

Subject Number	Selected Interim Behaviors	General Timeout Behaviors	Other
110	R ₄	R ₄ , R ₁₈ , R ₁₁	
111	R ₄	R ₄ , R ₈	R ₅
112	R ₈ /R ₄	R ₈ , R ₄ , R ₁₈	R ₆ , R ₁
113	R ₄	R ₄ , R ₈ , R ₉	R ₃ , R ₁₇
101	R ₄	R ₄ , R ₉ , R ₃	
102	R ₄	R ₄	R ₁₈ , R ₁₉
103	R ₁₉ /R ₄	R ₁₉ , R ₄	R ₁₇ , R ₁
104	R ₁₈	R ₁₈ , R ₄	

¹Selected and adapted from Staddon and Simmelhag (1971).

²Behaviors under General Timeout category are listed in order from most frequently to less frequently observed modes of behavior qualifying for this response class.

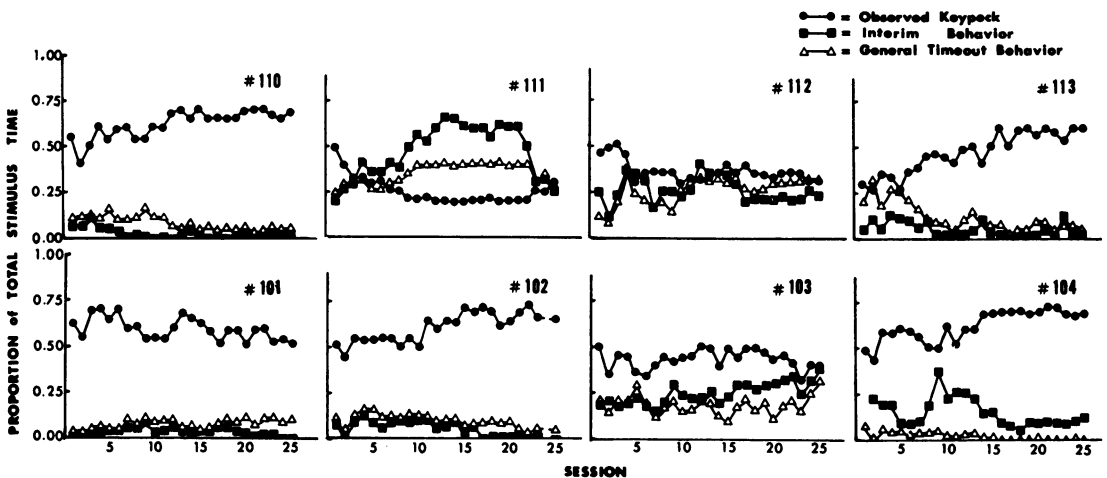


Fig. 4. Proportions of total stimulus-on periods occupied by three behavior classes throughout S+ only training.

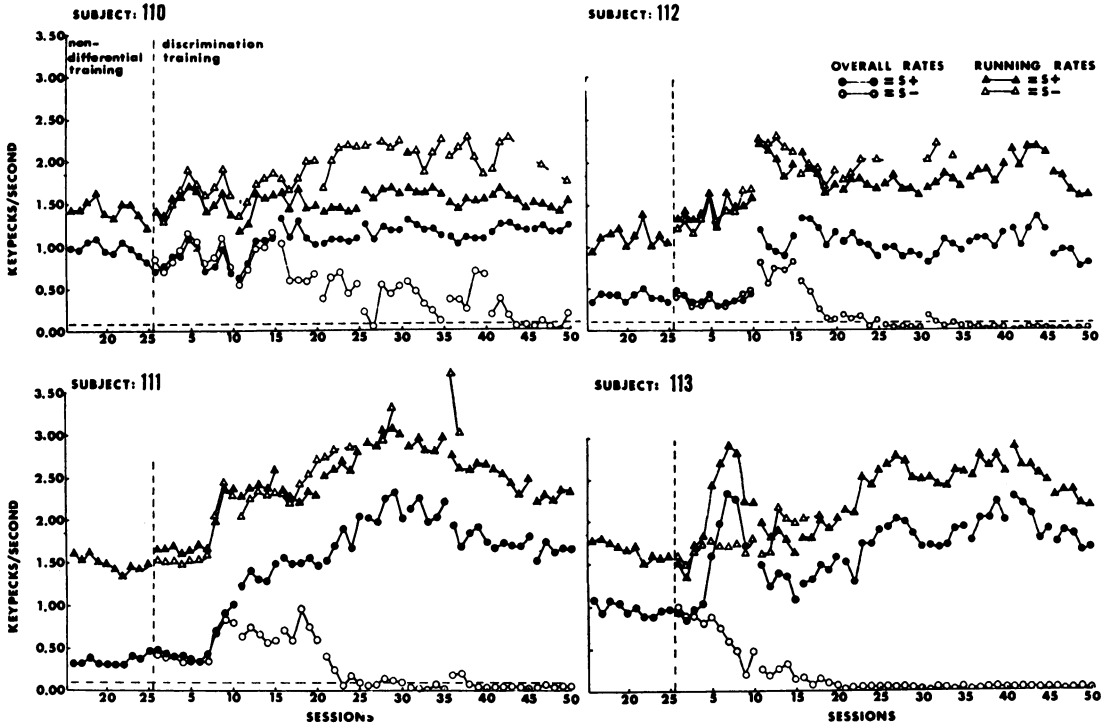


Fig. 5a. Overall and running rates of key pecking across all discrimination training sessions. Data points representing those discrimination training sessions separated by generalization tests are not connected (e.g., 10 and 11, 15 and 16, etc.). Running rates were not computed for those sessions in which the overall rates were less than 0.10 key pecks per second. See text for further details. Subjects 110 through 113.

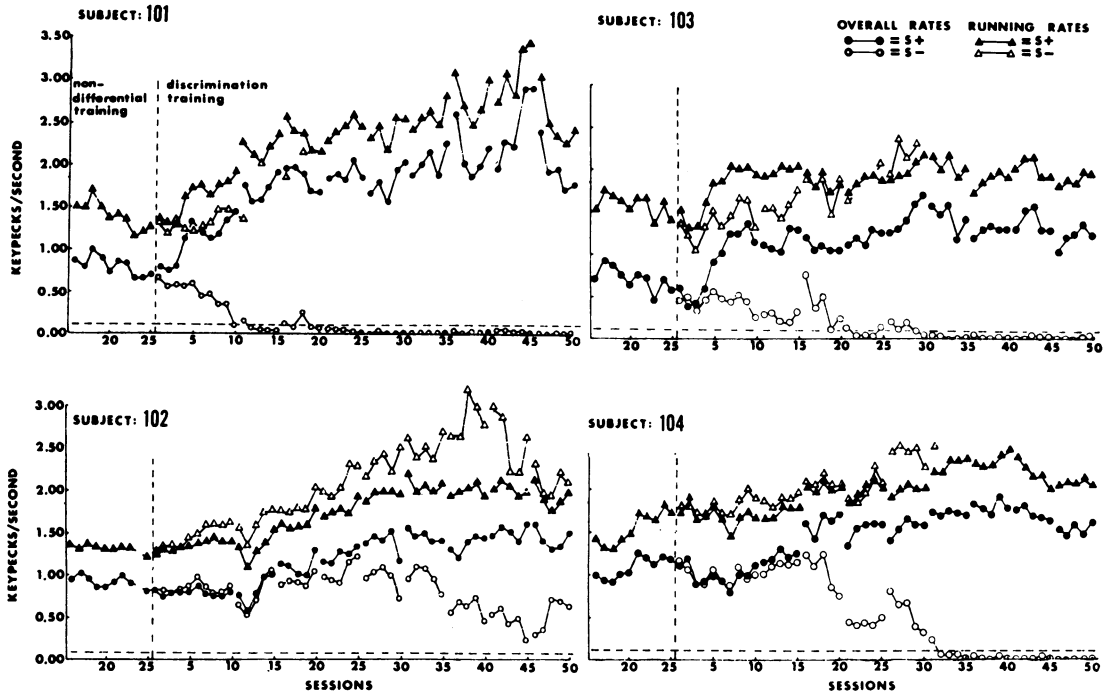


Fig. 5b. Overall and running rates of key pecking across all discrimination training sessions. Subjects 101 through 104.

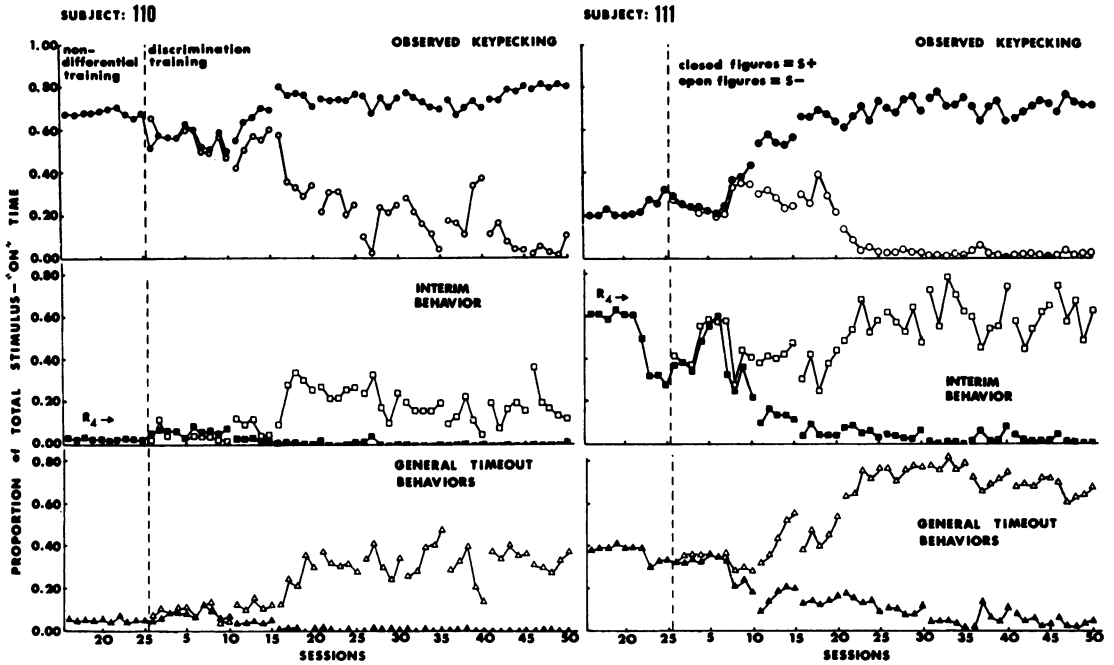


Fig. 6a. Proportions of total stimulus time occupied by three observed response classes. Subjects 110 and 111.

training (and two generalization test sessions), the schedule of reinforcement was increased from VI 60-sec to VI 20-sec in an attempt to facilitate development of the discrimination.

This schedule change was implemented for all subjects during Sessions 16 through 20, whether or not they had demonstrated differential performance in any of the three re-

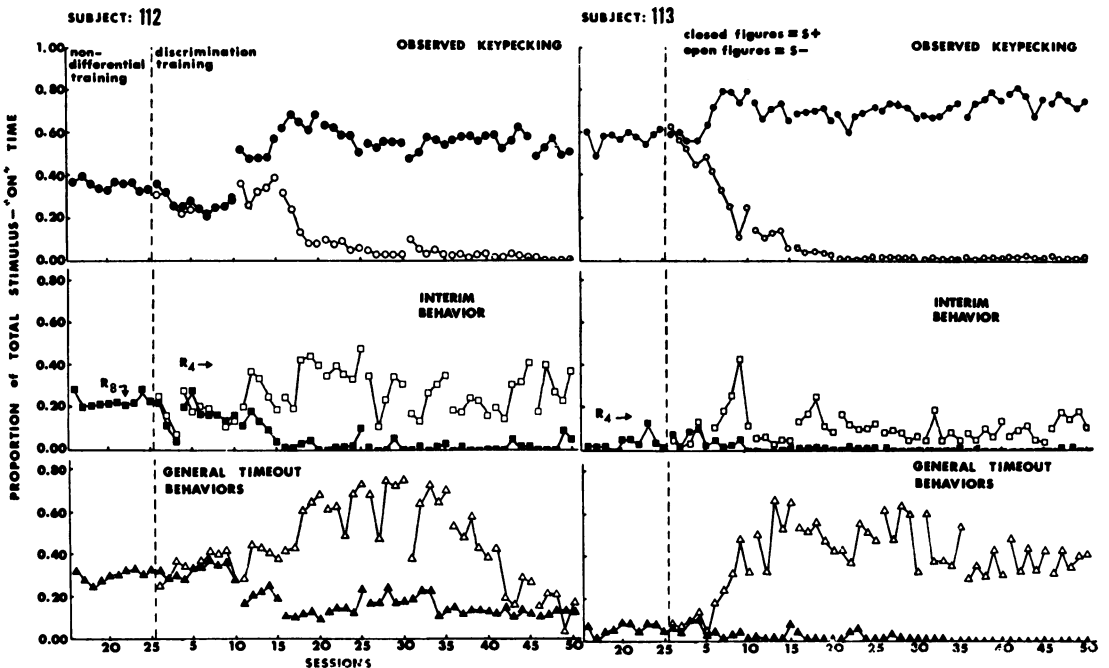


Fig. 6b. Proportions of total stimulus time occupied by three observed response classes. Subjects 112 and 113.

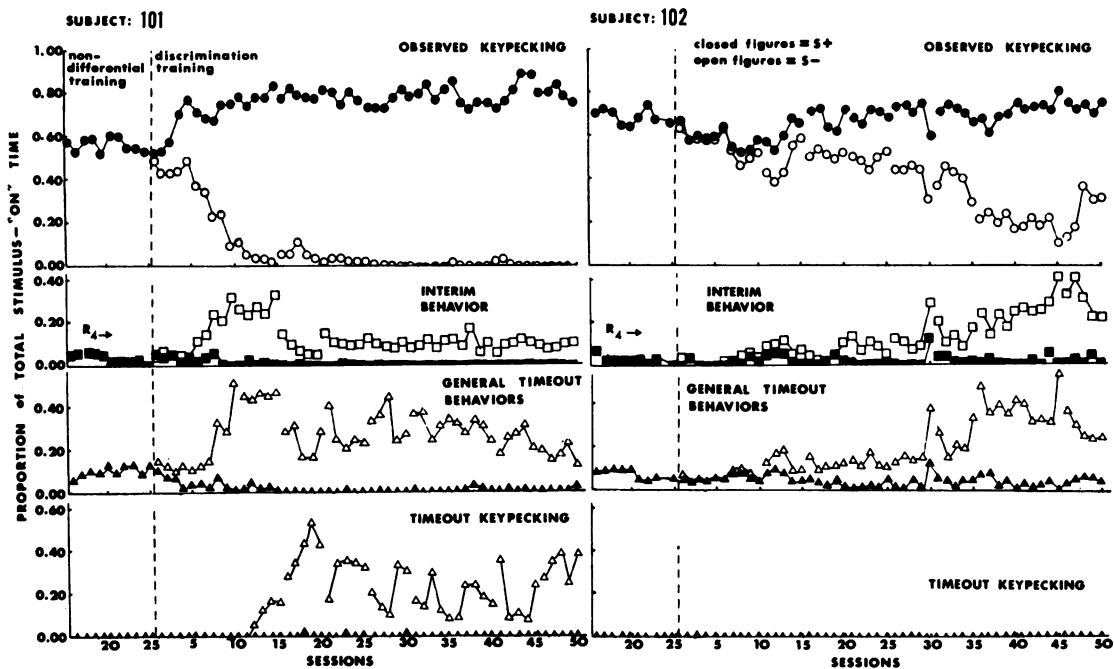


Fig. 6c. Proportions of total stimulus time occupied by three observed response classes and by timeout-key pecks. Subjects 101 and 102.

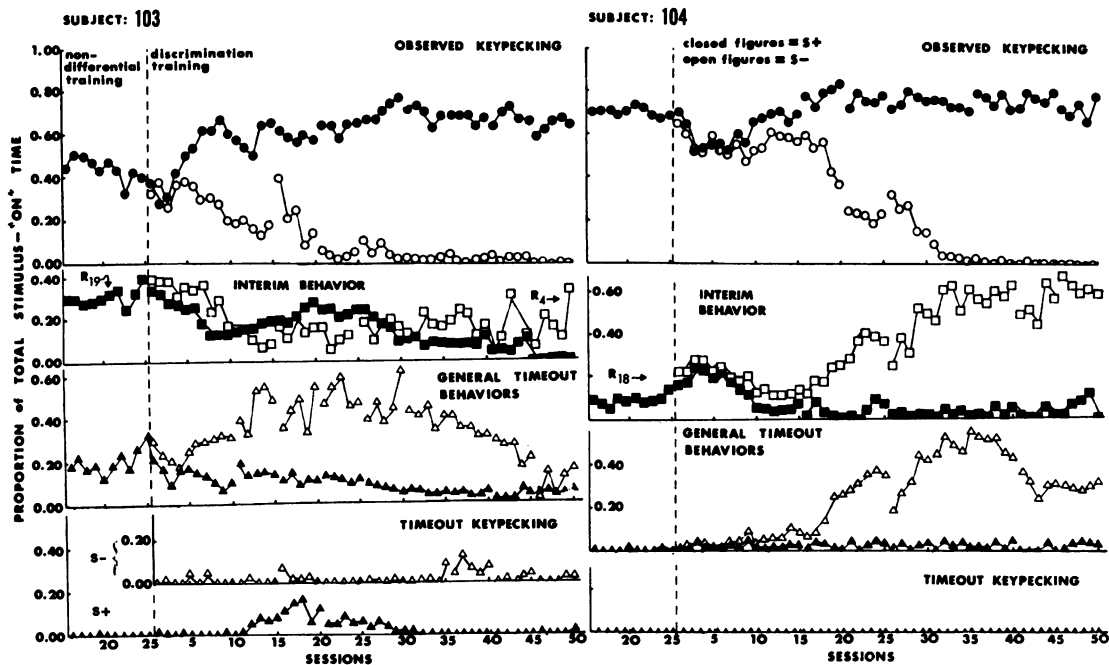


Fig. 6d. Proportions of total stimulus time occupied by three observed response classes and by timeout-key pecks. Subjects 103 and 104.

sponse classes. The VI 60-sec was re-instated on discrimination training session 21 and was in effect for the remainder of the experiment. Figures 5 and 6 show that the higher frequency of reinforcement was accompanied by an improved discriminative performance for most of the subjects. It appeared to have a temporarily disruptive effect for Birds 111, 101, and 102.

Key-pecking behavior. Figure 5 shows that with continued differential training, the overall rate of main-key pecking decreased in the presence of the S-. This decrease was accompanied by a corresponding decrease in the duration of observed main-key pecking (Figure 6). Figure 5 also presents the running rates of the S- key-pecking response, where it can be seen that the S- running rates remained as high as, and in several cases slightly exceeded the S+ running rates. The decrease in the overall rates of S- key pecking appeared, therefore, to be primarily a function of the decrease in the amount of time engaged in this behavior.

The running rates were not computed for those sessions in which the overall rate of key pecking was less than 0.10 responses per second. Such low overall rates often reflected isolated pecking responses, resulting in the observer "tracking" each key peck in a discrete fashion, *i.e.*, each peck was recorded as $\frac{1}{3}$ sec, since the timing device was set at three pulses per second. Thus, when each peck was recorded discretely, the running rates would spuriously approach 3.00 pecks per second. For those overall rates greater than 0.10 per second, the key pecks usually occurred in bursts of several responses.

The overall key-peck rates to the S+ also increased over the baseline rates when the S- key-pecking behaviors were decreasing. This phenomenon, known as behavioral contrast, was obtained fairly early in training for Birds 101, 103, 111, 112, and 113. Contrast emerged somewhat later for the other birds. It appears that introduction of the VI 20-sec schedule did not disrupt the contrast effects. Time allocated to S+ key-pecking behavior also increased, but the running rates indicate that this increase in overall rates was not solely a function of increases in the amount of time spent key pecking.

Interim behavior. Figure 6 illustrates that as the S- key pecking was being extinguished,

the S- interim behaviors were increasing for most subjects. Two exceptions to this finding are Subjects 103 and 112. The interim behavior observed during baseling training for Bird 103 was repetitive head movements toward the general vicinity of the timeout key. Discrimination training did not, however, result in differential performance with respect to this behavior class, as it occupied approximately equal portions of both S+ and S- stimulus-on periods. Because of the relationship of this behavior class to the behavior of pecking the timeout key, which occurred in the presence of both S- and S+, a decision was made to continue recording this behavior as the selected interim activity. Unfortunately, this choice sacrificed other behaviors that appeared to occur with some regularity in the presence of the S-, such as turning away from the key and facing the rear wall. The behavior of turning was recorded as the interim activity during the last training block (Sessions 46 to 50) where it occurred almost exclusively in the presence of the S-.

The interim behavior for Subject 112 (pacing movements at the key wall, accompanied by vigorous wing flaps) was observed during the S+ only training phase, but dropped off sharply in the early stages of discrimination training and was replaced by another behavior, turning around in the chamber, which was then selected as the interim behavior.

General timeout behaviors. Figure 6 shows that as the S- key pecking decreased, the amount of time in which the birds removed the stimulus from view increased and generally remained high throughout the experiment. Toward the end of the experiment, the S- general timeout behaviors of these three birds decreased substantially. Birds 103 and 112 were observed to be spending an increasing amount of time directly in front of the key, engaging in what are described as roosting behaviors. Bird 104 continued to engage in the interim behavior of turning to the right side of the chamber, although less of this behavior also qualified for the general timeout classification, *i.e.*, it would turn to the right but well within the area of direct illumination from the stimulus lamp.

Timeout-key pecking. Figure 6 shows that only two (103 and 101) of the four birds in Group II pecked the timeout key with any regularity. In the case of 101, this response

was highly variable, but was maintained throughout the experiment. In the early stages of discrimination training, the timeout-key peck for 103 occurred in the presence of the S+, an unexpected result since the frequency of the obtained reinforcement was diminished (the tape programmer stopped during the S+ timeouts). It appeared that the S+ timeout-key peck was embedded in the interim behavior of head movements toward the general vicinity of the timeout key. Toward the end of discrimination training, the timeout-key pecks occurred more often during the S- periods.

Analysis of timeout-key responses as a function of the portion of the S- intervals showed that they were more frequent in the last two-thirds of the interval. It was also found that in 63% and 44% of the intervals in which a timeout-key peck occurred, Birds 101 and 103, respectively, engaged in turning away from the manipulanda wall before pecking the timeout key.

Generalization Testing

In addition to the traditional gradients of overall rates of key pecking, results of gener-

alization testing include gradients of running rates of key pecking, timeout-key pecks, interim behaviors, and general timeout behaviors. The test procedure was administered after the first 10 discrimination training sessions and subsequently after each block of five training sessions. Nine such tests were given and provided the means of tracking the development of the discrimination and of detecting changes in the degree of stimulus control over the course of the experiment. Figure 7 presents the results of the first, middle, and last of the nine tests. For all subjects, these three tests are representative of the trend throughout the testing procedure.

Key-peck gradients (overall and running rates). Figure 7 reveals that once the discrimination was acquired, the overall rates of key pecking systematically decreased when the test stimuli were varied away from the S+ training value. The running rates, however, suggest that these different overall rates are best accounted for in terms of differences in time occupied by this behavior class, *i.e.*, when the birds were pecking the main key, they did so at a relatively constant tempo.

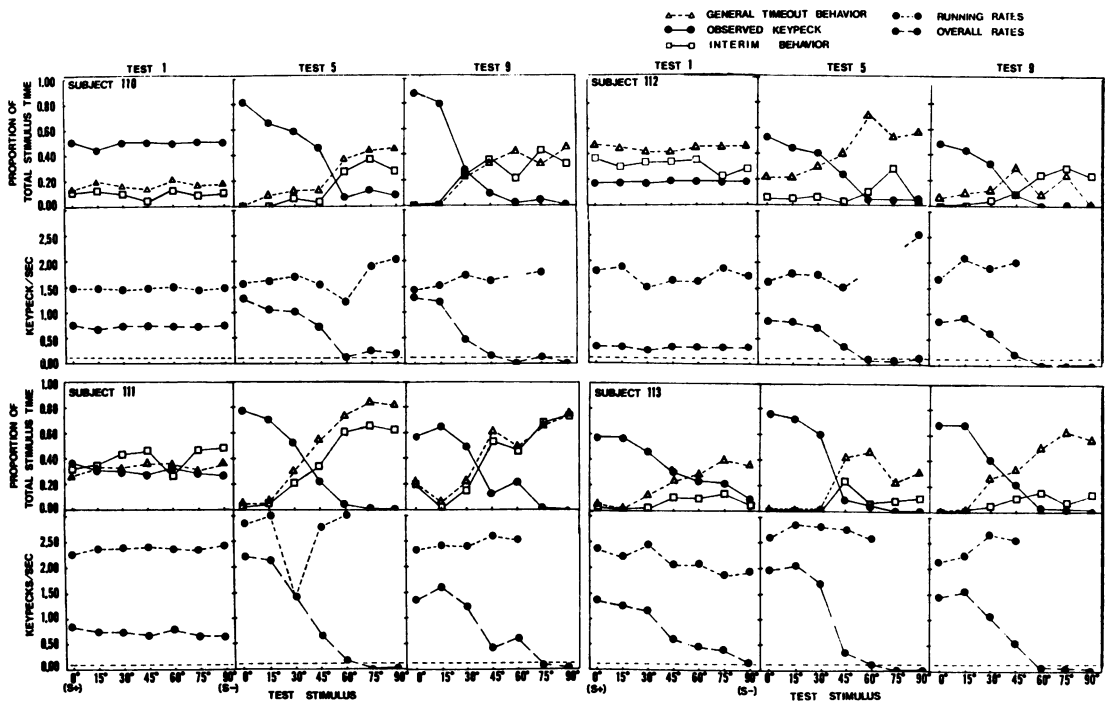


Fig. 7a. Generalization gradients (Tests 1, 5, and 9) of the three observed classes of behavior (upper portion of each test panel) and overall and running rates of key pecking (lower portion of each test panel). Subjects 110 through 113.

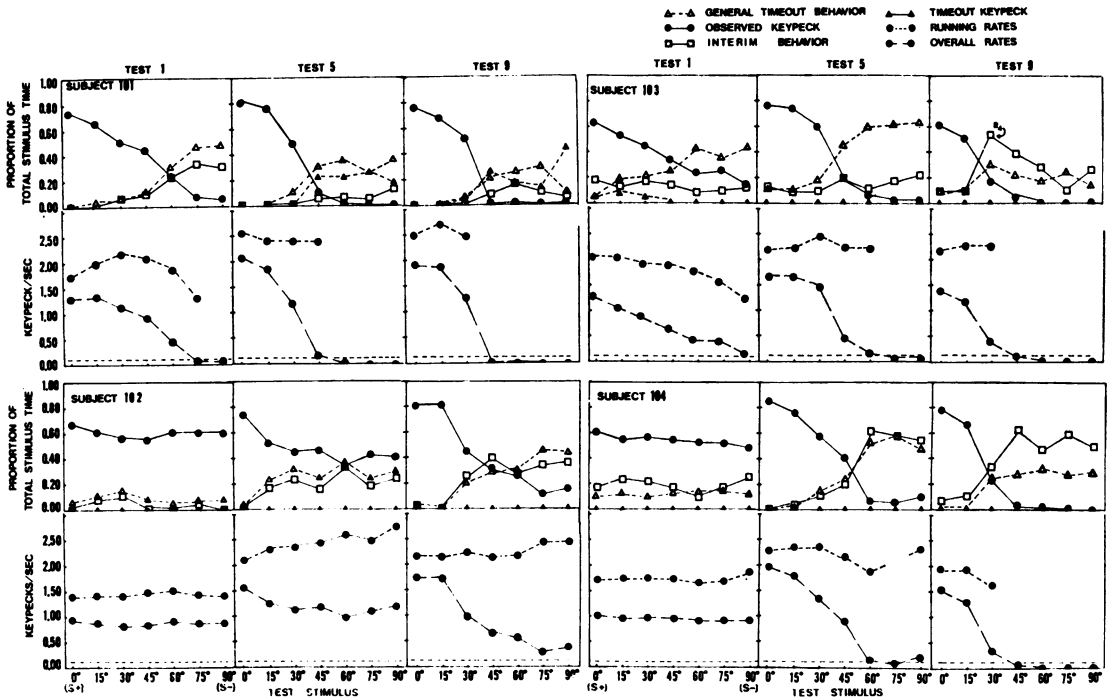


Fig. 7b. Generalization gradients (Tests 1, 5, and 9) of the three observed classes of behavior and timeout-key pecks (upper portion of each test panel) and overall and running rates of key pecking (lower portion of each test panel). Subjects 101 through 104.

Interim behaviors, general timeout behaviors, and timeout-key peck gradients. For most subjects, the amount of time occupied by the interim behaviors and the general timeout behaviors decreased as the test orientations were varied from the S- training value. The timeout-key peck behaviors of 101 were under control of the S-, as evidenced by the fact that they decreased in frequency as the test stimuli were varied away from the S- training value. Timeout-key pecks of 103 were infrequent but suggest S+ control in the first generalization test.

As discrimination training progressed, the slopes of these gradients increased, indicating a greater degree of stimulus control. This sharpening effect was attributed to the fact that the generalization test was in reality a modified discrimination training procedure, in that each test block was separated by re-training conditions in order to maintain responding throughout the test sessions. Such a procedure established the 45-, 60-, 75-, and 90-degree test values as functionally equivalent S-s.

DISCUSSION

As in previous studies of this kind (*e.g.*, Jenkins and Harrison, 1960), the frequency of responding was a useful index of differential performance. Discrimination training resulted in high overall rates of the key-peck response to the S+, low overall rates to the S-, and intermediate rates to intermediate stimulus values. In addition, observations of the key-peck response revealed similar changes in the proportion of time engaged in this class of behavior; high key-peck proportions were found in the presence of S+, low proportions in the presence of S-, and intermediate proportions in the presence of the intermediate test stimuli. Considering only the class of key pecking, differential performance can, therefore, be adequately represented by absolute changes in the number of key pecks or the amount of time the organism actually spends engaging in the key-pecking activity.

On the basis of these results, two measures appear to have equal utility in describing performance of an organism in a simple discrimi-

nation learning task. Where interest is focused on behaviors other than those that are readily digitized, however, describing performance in terms of time allocation may be more advantageous, especially since it affords direct comparison with other topographically different behaviors that are more readily measured in units of time.

An additional advantage is that the measure of overall rate is susceptible to the notion that it is an index of the tempo of discrete occurrences of the conditioned response. Thus, it may be assumed that as the rate to the S— decreases, the tempo with which the organism strikes the key is similarly decreasing. The running rates obtained by dividing the total number of key pecks by the observed time occupied by this behavior are a more appropriate measure of the tempo of such responding, since the time base excludes portions of the interval in which the organism is engaging in behaviors away from the key. The running rates showed that, for the most part, when the birds pecked the key, they did so at a relatively constant tempo, despite substantial differences in overall rates between the two training stimuli and among the various test stimuli.

These data are compatible with those of Blough (1963), who performed an inter-response-time (IRT) analysis of the key-pecking response as a function of the shift from VI 4-sec to extinction. As extinction progressed, the distribution of IRTs remained approximately the same, *i.e.*, the peak duration remained at approximately 0.4 sec, although the number of long IRTs (from a few seconds to several minutes) increased. Schaub (1967) also found that changes in overall rates during discrimination training and generalization training reflected changes in the long IRT class, rather than a shift in the IRT distribution as a whole. Observational data from the present investigation strongly suggest that these longer IRTs are times occupied by specific behaviors other than key pecking. Thus, the effect of altering the discriminative stimulus appears to be that of altering the proportion of time in which the S+ conditioned response occurs, rather than having the effect of speeding up, or slowing down, the rate of occurrence of discrete key pecks.

With respect to behavioral contrast, the present study showed an increase in time allocated to S+ key pecking in six of eight sub-

jects. Bouzas and Baum (1976) also observed behavioral contrast of time allocated to pigeons' standing on a platform. If, however, contrast of overall rates of key pecking were solely a function of increases in time allocated to this behavior class, the running rates should have remained constant. Results showed this not to be the case, as the running rates in seven of eight subjects increased substantially in the initial phases of differential responding.

Recent evidence strongly suggests that rather than simple acceleration of homogeneous members of the class of key pecking, positive behavioral contrast might be attributed to an addition of key pecks that differ from other key pecks in terms of their controlling stimuli (*e.g.*, Gamzu and Schwartz, 1973; Keller, 1974; Schwartz, Hamilton, and Silberberg, 1975). Gamzu and Schwartz (1973) found, for example, that when two component stimuli of a multiple schedule signalled different schedules of food delivery, key pecking was observed despite the absence of any explicit contingency to do so. Rachlin (1973) suggested that in the multiple schedule, these extra "unconditional" responses are superimposed on the operant response, leading to the increased overall rate of key pecking. The addition of such responses may account for the dramatic increase in the tempo of key pecking observed in the present study. Thus, an adequate analysis of contrast of overall rates of key pecking appears to require consideration of increases in *both* tempo and time allocated to key pecking.

We turn now to a discussion of differential performance in terms of topographically distinct classes of behaviors. The present results indicate that in a simple discrimination task, the organism engages in a variety of highly active stereotyped behaviors when not engaging in the response conditioned to the S+. These nonkey-peck behaviors occupied a considerable portion of the S— intervals during discrimination training, and they systematically increased as the orientation of the line was rotated away from the S+ value and toward the S— value during generalization testing.

Speculating briefly on the nature of these S— behaviors, it was originally suggested that the gross behaviors and the timeout-key pecks may be considered members of a functionally equivalent class of behaviors defined by the

consequence of removal of the S-. The high degree of overlap between the selected interim behavior and the general timeout behaviors tentatively suggests that the birds may indeed have been engaging in activities that removed them from the direct illumination of the stimulus lamp. It is important to note that in no case did the subjects systematically engage in monkey-peck behaviors that did not also meet the general timeout criterion at some point in the execution of each of those behaviors, e.g., turning around, pacing along the walls of the chamber, etc. Any conclusion regarding the precise relationship (i.e., substitutability) between the gross behaviors and the timeout-key pecks, however, demands more than tenuous correlational data. What is needed is some type of direct manipulation of the timeout contingencies in various experimental situations.

In conclusion, it is clear that decreases in the conditioned response can be described as decreases in the amount of time devoted to this behavior relative to other highly active and specifiable activities in an organism's behavioral repertoire. As the amount of S- time occupied by the S+ conditioned response declines, the amount of time occupied by these other specific behaviors correspondingly increases. What is evident, on the basis of these observations, is that when the organism is not engaging in the conditioned response, a lot is happening and these other behaviors warrant serious attention in a complete analysis of discrimination learning.

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