THE EFFECTS OF REINFORCEMENT UPON THE PREPECKING BEHAVIORS OF PIGEONS IN THE AUTOSHAPING EXPERIMENT[1]

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The autoshaping procedure confounds the effects of pairing a keylight and food with the effect of adventitious food reinforcement of responses that typically occur before the pecking response. In Experiment I, acquisition of the orientation to the key, the approach toward the key, and the peck at the key were systematically monitored. Orientations to the key and approaches toward the key frequently occurred in contiguity with food presentation before peck acquisition. In Experiment II, a negative contingency procedure was used to assess the sensitivity of the approach toward the key to its consequences. When the approach toward the key resulted in nonreinforcement, the probability of occurrence of that response decreased to zero despite repeated light-food pairings. In Experiment III, peck probability was shown to be determined during the approach toward the key by the presence of stimuli that had previously been either paired or nonpaired with food. In Experiment IV, it was shown that the effects of the stimulus present during the approach toward the key were not due solely to the effects of pairing that stimulus with food. Autoshaped key pecking appears to be determined by the interacting effects of stimulus-reinforcer and response-reinforcer variables upon orientations to, approaches toward, and pecks at the lighted key.

Brown and Jenkins (1968) first reported that response-independent, forward pairings of a briefly lighted key with food presentation reliably resulted in acquisition of the key peck in the pigeon. The operations of pairing a briefly lighted key with food presentation independently of the subject's behavior will hereafter be referred to as the response-independent procedure. These results, along with those of a variety of other studies (see Trapold and Overmier (1972) for an excellent review) show that Pavlovian conditioning operations (response-independent pairings of two stimuli) can determine the probability of occurrence of directed skeletal behaviors. Brown and Jenkins (1968) and others (e.g., Gamzu and Williams, 1971; Gamzu and Schwartz, 1973) have shown that the stimulus variables known to determine the probability of occurrence of a conditioned response in more conventional Pavlovian conditioning preparations also exert strong control over the probability of key pecking in the response-independent procedure.

A comprehensive account of the effects of stimulus-food pairings on directed skeletal behaviors in the pigeon will not be available until the behaviors that are conditioned have been analyzed more carefully. Of the behaviors that occur in the response-independent procedure, only the key peck has been studied extensively. Behaviors other than the key peck may, however, be conditioned in the response-independent procedure. Brown and Jenkins (1968) observed that nonpecking responses increased in frequency and occurred reliably before acquisition of the key peck. Specifically, those authors noted (p. 3) that after 10 or 20 pairings of the lighted key with food presentation, movement patterns controlled by the presence of the light had been conditioned. In contrast, acquisition of the key peck occurred following 45 pairings on the average. The behaviors that occur antecedent to acquisition of the key peck have not been studied experimentally.

The experimental analysis of conditioned nonpecking behaviors in the response-inde-

pendent procedure seems particularly important for the analysis of autoshaped key pecking. In stimulus-stimulus pairing situations, once a response is conditioned (as measured by an increased probability of occurrence during the conditioned stimulus), it may be affected by the events which follow it. For example, Schwartz and Williams (1972) showed that the pecking that occurs following light-food pairings is sensitive to its consequences even though the original occurrence of pecking could not have been due solely to adventitious reinforcement of either pecking or non-pecking behaviors (Williams and Williams, 1969). Since nonpecking directed behaviors may be conditioned before key-peck acquisition in the response-independent procedure, those nonpecking responses may be affected by their consequences before the first occurrence of a key peck. Therefore, the effects of differential stimulus-food pairings upon the acquisition of the key peck are confounded with the possible effects of reinforcement upon antecedent, nonpecking behaviors. It is possible that the effects of stimulus-food pairings interact with the effects of response-food pairings at all stages of conditioning in the response-independent procedure. A step towards determining the existence and possible role of such interactions may be made by an experimental analysis of all behaviors that are conditioned in the response-independent procedure.

The primary purpose of the present experiments was to describe rigorously the occurrence of all key-directed behaviors in the response-independent procedure, and to analyze experimentally the effects of reinforcement upon one of the antecedent directed behaviors. The experiments were designed such that preliminary information concerning the stimulus control of various key-directed behaviors could be obtained.

EXPERIMENT I

In previous pilot experiments in which a response-independent procedure was used, the author made casual yet extensive observations of the behaviors of pigeons other than those that served in this experiment. No clear effects of reinforcement of antecedent behaviors upon the probability of occurrence of the key peck were discernible. However, for each subject, certain key-directed behaviors reliably occurred before acquisition of the key peck. All key-directed behaviors seemed to fall into one of three descriptive categories. These categories were not formulated on the basis of *a priori* considerations; the categories most completely described all of the key-directed behaviors observed.

The purpose of this experiment was to monitor systematically the acquisition in the response-independent procedure of the three most obvious directed behaviors that had been reliably observed by the author in previous experiments.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons, three to nine months old, bred from stock originally obtained from the Palmetto Pigeon Plant, were maintained at 80% of their free-feeding weights for the duration of the experiment.

Apparatus

A standard Lehigh Valley experimental chamber for pigeons was used. Standard scheduling and recording equipment were located in an adjacent room. White noise was constantly delivered through a speaker mounted on the front wall, and the sound of the ventilating fan of the chamber provided additional masking noise. Diffuse illumination was constantly provided by a houselight located centrally on the front wall, 2.5 cm from the ceiling. The houselight was a GE 44 bulb (1.8 W) operated at 6 V dc. The bulb was unhoused so as to allow for sufficient illumination for recording purposes. The hole for the observation window of the chamber was covered on the inside by a sheet of clear plastic and on the outer surface by a one-way window.

Of the two keys mounted on the front panel, only the left key was used in the experiment. The stimulus projected on the key was a white line (3.2 mm in width) on a black background. The stimulus was selected from one of eight, 6-V lamps (1.5 W) housed in an in-line display cell (Industrial Electronics Engineers). The following angular orientations of the white line were used: 8.2°, 24.6°, 32.8°, 41.0°, 49.2°, 57.4°, 73.8°, and 90.0°.

The behaviors of the subjects were recorded by using the following Sony video taping equipment: AVC-3200 camera, AV 3650 recorder with slow-motion capabilities, and CVM-9204 monitor. During each session, the camera was located at a constant point outside of the observation window of the chamber.

Procedure

Each subject was placed in the chamber for 15 min on successive days. The chamber was illuminated only by the light housed inside the feeder aperature, and mixed grains were continuously available. This procedure continued until the subject ate from the hopper. During the next session, the houselight was turned on and the subject was trained to approach and eat readily from the hopper. Food was presented independently of the subject's behavior according to a VI 30-sec schedule (Fleshler and Hoffman, 1962). Duration of food access was progressively decreased to 4 sec, and remained at that value throughout the experiment. During these magazine training sessions, the response key remained darkened.

Following magazine training, each subject was exposed to a response-independent procedure. Occurring at the same 30-sec variable intervals used in hopper training were 20 trials consisting of a 6-sec illumination of the key followed immediately by 4 sec of access to grain. During these trials, hereafter referred to as S+ trials, the 41.0° white line was projected on the key. Randomly interspersed among the 20 S+ trials were seven presentations of the lighted key alone. During these unpaired keylight presentations, a white line of orientation other than 41.0° was presented. Each of the seven other stimuli was presented once in each session and the order of presentation was random. These seven stimuli were presented so that the stimulus control of key-directed behaviors could be assessed. The stimulus control data are not directly relevant to this report and will be described in a forthcoming manuscript.

During either type of trial, no behaviors had any scheduled consequences. During the intertrial interval, the key remained darkened and those pecks that resulted in microswitch closures delayed the onset of the next trial by 5 sec.

Procedure for Describing Behaviors

Following the experimental session, the videotaped record of intratrial behaviors was displayed in slow motion (one-tenth of normal playback speed). On a table directly in front of the seated observer was a panel upon which were mounted 16 push buttons, each of which corresponded to a particular category of behavior. The video monitor was located at the other end of the table and faced directly toward the observer at all times. Each response of the observer was fed directly into an eight-channel, binary-coded tape punch unit that automatically recorded the time between successive events to the nearest tenth of a second. This taped record provided information concerning both the frequency and duration of each behavior, and provided a record that was easily analyzable by computer.

Behaviors were described as belonging to one of 16 categories quite similar to those used by Staddon and Simmelhag (1971). The major difference was that here three categories of key-directed behaviors were used. Only the key-directed behaviors will be described fully since they are of major concern in this experiment. Those behaviors were: (1) the orientation to the key, (2) the approach toward the key, and (3) the peck at the key.

The orientation to the key should not be confused with the orienting reflex discussed by Sokolov (1963). The orientation to the key included two clearly discriminable types of response, both of which could be described as "looking toward the key". The first type consisted of a brief cessation of movement after a turning of the beak toward the key. During this binocular orientation, the subject's beak pointed directly toward the key. The second type consisted of a turning of the head such that one of the subject's eyes directly faced the key. For the latter response, all head and trunk movements ceased momentarily, and the one eye was held at the same height as the key. The topography of the orientation to the key proved to be quite discernible during the slow-motion playback, and so no guessing as to whether or not the subject actually "saw" the key was required of the observers or is implied in the description. The approach toward the key consisted of any movement of the head or trunk that brought the subject relatively closer to the key. The key peck

consisted of any pecking movement directed toward the key.

Although there is a large degree of overlap between these categories, they were treated as if they were mutually exclusive so as to allow finer discriminations between behaviors to be made. For example, although the key peck is a specialized type of approach toward the key, a peck at the key was scored only as a key peck, rather than the joint occurrence of an approach toward the key and a peck at the key.

RESULTS AND DISCUSSION

Table 1 shows for each subject the frequency with which directed behaviors occurred within successive blocks of five S+ trials. Table 1 shows that over S+ trials, there was an increased frequency of occurrence of orienting to the key, approaching toward the key, and pecking at the key within each segment of S+ trials. Table 1 also shows that over S+ trials there was an increased frequency of occurrence of the response sequence consisting of an orientation to the key followed immediately by an approach toward the key.

Generally, there were no systematic differences in the frequency of occurrence of any directed behavior across successive trial segments. For example, P5 and P11 pecked at the key with increased frequency across trial segments, but P2 pecked more frequently in the first trial segment. In the last sessions of the experiment, both P5 and P11 approached toward the key most frequently during the first trial segment, but this trend was not present for P2. Similarly, the orientation-approach sequence occurred most frequently during the first trial segment for P5 and P11, but not for P2. The decreased frequency of occurrence of the approach toward the key and the orientation-approach sequence across trial segments was due to the fact that after acquisition of the key peck had occurred, P5 and P11 were most often positioned directly in front of the key and were pecking at the key. For P2, the orientation-approach sequence and the approach toward the key did not occur less frequently over trial segments as the experiment proceeded. P2 continued to orient to and approach toward the key in the latter trial segments with the same frequency as in the first trial segment. Therefore, the

decreased frequency of pecking across trial segments for P2 was not accompanied by a simultaneous decrease in the frequency of occurrence of all directed behaviors across trial segments. The antecedents of the differences between the pecking behaviors of the different subjects are not clear.

The rates of acquisition of directed behaviors varied among subjects, but the following trends were present for each subject. Orienting to and approaching toward the key increased simultaneously in frequency before the first occurrence of a peck at the key. It is important to note that, for each subject, these nonpecking behaviors were occurring with increased frequency in the third segment of the S+ trials before acquisition of the key peck. Table 1 shows that there were differences among subjects with respect to how soon acquisition of the key peck occurred following the increased frequency of occurrence of the nonpecking behaviors.

Since these directed nonpecking behaviors occurred in temporal contiguity with food presentation and increased in frequency of occurrence, the conditions that define operant conditioning were met with respect to those behaviors. Examination of the records revealed that even though these directed behaviors occurred frequently in the final 2.0-sec segment, there was little increase in the frequency with which key-directed behaviors occurred as the very last intratrial behavior. This finding is consistent with the observations of Rachlin (1969). He photographed his subjects at the moment of food presentation in a response-independent procedure, and found that key-directed behaviors did not reliably occur just prior to food presentation before the acquisition of the key peck.

Figure 1 shows that the increased frequency of occurrence of the orientation-approach sequence found in the third trial segment occurred before the acquisition of the key peck. To emphasize this fact, the cumulative frequency of key pecking across S+ trials is shown. The cumulative frequency of pecking was calculated as the total number of key pecks for a particular trial block plus the total number of key pecks that had occurred in all preceding trial blocks. For P5 and P2, key-peck acquisition occurred soon after the orientation-approach sequence increased in frequency, while for P11, the course of key-

Table 1

The frequency of occurrence of key-directed behaviors within successive 2.0-sec segments of S+ trials over successive blocks of five S+ trials. Different numbers of S+ trials are shown for each subject since the acquisition of the key peck occurred at different rates for the different subjects. O = orientation to the key. A = approach toward the key. O A = orientation-approach sequence. P = peck at the key.

S+ Trial Block	P5 Trial Segment												P11 Trial Segment												P2 Trial Segment											
	0 sec-2 sec				2 sec-4 sec				4 sec-6 sec				0 sec-2 sec				2 sec-4 sec				4 sec-6 sec				0 sec-2 sec				2 sec-4 sec				4 sec-6 sec			
	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P	O	A	OA	P
1	1	0	0	0	1	1	0	0	3	2	1	0	13	5	2	1	4	2	2	0	6	5	2	0	1	1	0	0	1	2	0	0	2	0	0	0
2	0	0	0	0	2	4	0	0	5	2	2	0	2	4	1	0	10	6	4	0	6	4	4	0	7	4	3	0	1	0	0	0	3	0	0	0
3	4	0	0	0	2	0	0	0	0	1	0	0	9	5	4	0	9	4	4	0	10	8	7	0	2	0	0	0	5	3	1	0	5	2	0	0
4	2	0	0	0	3	2	1	0	0	2	1	0	13	7	7	0	10	5	4	0	11	6	6	0	1	3	0	0	0	1	0	0	0	0	0	0
5	4	1	0	0	3	2	0	0	0	1	0	0	12	4	1	0	12	4	4	0	10	7	7	0	0	0	0	0	1	1	0	0	0	0	0	0
6	3	1	1	0	2	2	0	0	4	3	2	0	19	6	6	1	11	5	5	4	12	6	4	2	2	0	0	0	1	1	1	0	1	2	1	0
7	2	0	1	0	7	2	2	0	3	2	1	0	15	5	4	3	10	3	3	5	13	5	5	4	1	2	0	0	1	2	0	0	3	0	1	0
8	3	1	1	0	6	3	2	0	6	3	2	0	12	4	3	4	12	3	3	6	13	5	1	9	4	2	2	0	2	2	1	0	1	1	0	0
9	3	2	0	0	6	4	3	0	6	4	4	0	11	6	5	9	6	0	0	12	6	0	0	18	0	2	0	0	0	1	0	0	3	1	1	0
10	8	3	2	0	6	2	1	0	6	4	4	0	11	5	5	18	7	2	2	20	7	1	1	29	1	1	1	0	4	2	0	0	6	3	2	0
11	7	3	2	0	5	3	1	0	13	7	7	1	12	5	5	13	7	0	0	22	6	0	0	26	5	3	2	0	4	2	1	0	3	3	2	0
12	6	3	3	0	6	4	4	2	13	4	4	3	13	5	5	9	3	0	0	21	7	0	0	31	1	1	0	0	2	1	0	0	3	1	2	0
13	16	7	7	1	10	1	1	7	16	7	5	8													4	3	2	0	2	1	0	0	3	1	2	0
14	9	3	3	2	9	2	2	6	12	6	5	12													7	1	0	0	3	2	1	0	4	2	1	0
15	11	5	5	2	10	3	3	7	15	2	2	13													4	2	2	0	3	2	2	0	2	1	2	0
16	14	5	5	7	7	0	0	16	8	0	0	16													3	0	0	0	7	2	2	0	4	2	2	0
17																									5	6	2	0	5	2	3	0	6	3	3	0
18																									12	4	3	0	4	4	4	0	10	4	4	0
19																									8	5	5	0	8	4	4	0	6	6	5	0
20																									12	8	7	1	8	5	4	0	8	4	5	1
21																									7	4	4	1	10	5	4	2	10	2	2	5
22																									10	3	3	2	10	3	3	5	10	3	4	6
23																									15	5	5	8	9	5	3	3	12	5	4	3
24																									10	6	5	10	11	3	4	5	10	4	4	5

peck acquisition did not follow so closely the change in frequency of that sequence. The data presented in Figure 1 are taken from Table 1. Figure 1 provides a graphical illustration of the confounding of stimulus-food pairings with response-food pairings that is inherent in the response-independent procedure.

P11 pecked the key on the first S+ trial, although reliable acquisition did not occur until later. Before key-peck acquisition, all subjects oriented to and pecked at different environmental stimuli, such as the houselight and the speaker. Such observations are consistent with those made by Skinner (1948) and by Staddon and Simmelhag (1971) in showing that directed behaviors occur with high probability in intermittent, free-feeding situations even apart from explicit stimulus-food pairings.

For the determination of interobserver reliability, 40 trials, during which behaviors were scored by two observers, were selected randomly from all trials scored by both. Trials scored by both observers were treated as a pair of observations in the computation of the correlation between the frequencies of occurrence of each behavior as scored by the two observers. The correlation coefficient (r) for the orientation to the key was 0.87, for the approach toward the key, 0.93, and for the peck at the key, 0.99. All correlations were significant (p < 0.01). Thus, interobserver reliability was very high for all directed behaviors.

The results of Experiment I show that at a relatively gross level of observation, three key-directed behaviors are conditioned in the response-independent procedure. Although orienting to and approaching toward the key must necessarily precede the occurrence of a peck at the key when the pigeon is standing at a distance from the key, orienting to and approaching toward the key occurred frequently before the first emission of a key peck for each subject. It is therefore plausible that the increased frequency of occurrence of the directed nonpecking behaviors was more than a necessary concomitant of key-peck acquisition. The latter view would be less plausible if, for example, approaches to the key had occurred with increased frequency only when there was a simultaneous increase in the frequency of occurrence of pecks at the key.
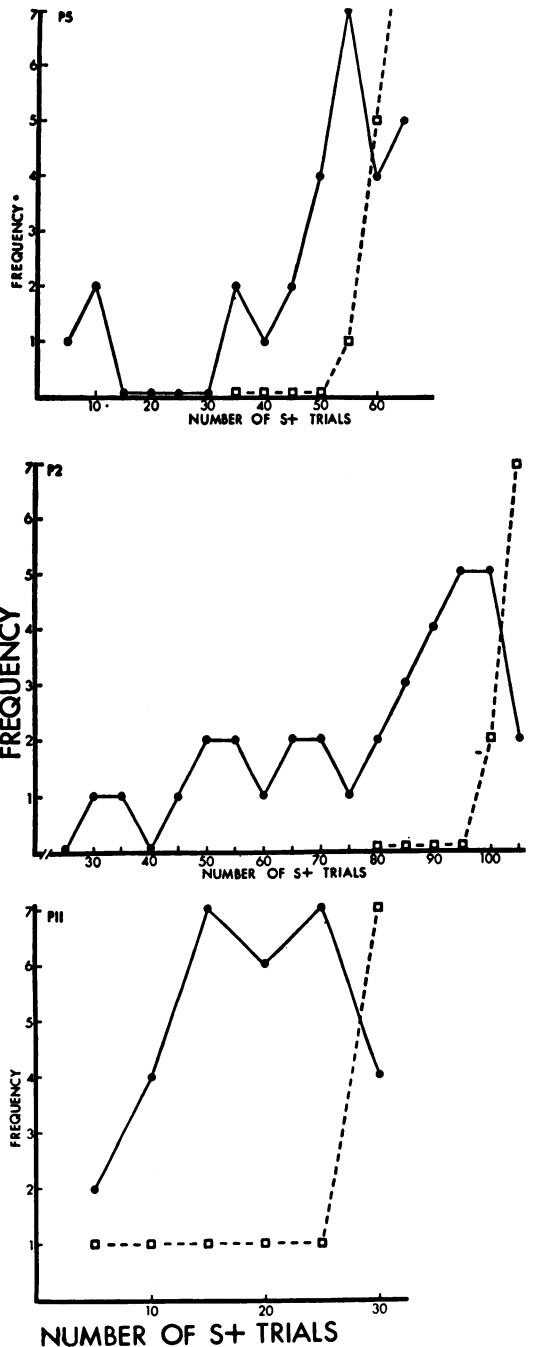

Fig. 1. The frequency of occurrence of the orientation-approach sequence (circles) and the key peck (squares) over S+ trials. The circles show the frequency with which the orientation-approach sequence occurred within the final 2.0-sec segment of blocks of five S+ trials. The squares show the cumulative frequency of occurrence of the key peck over all S+ trials. Each graph shows data collected from a single subject.

EXPERIMENT II

The effects of the occurrence of orientations to and approaches toward the key in temporal proximity to food presentation are unclear, since these events are confounded with the increased number of stimulus-food pairings. If the responses of orienting to and approaching toward the key were insensitive to their consequences, then the confounding of light-food pairings with response-food pairings inherent in the response-independent procedure would have trivial implications. The purpose of Experiment II was to determine the extent to which the approach toward the key is sensitive to its consequences. Accordingly, a negative contingency procedure similar to that used by Sheffield (1965) and by Williams and Williams (1969) was employed.

METHOD

Subjects

Two White Carneaux pigeons were maintained at 80% of their free-feeding weight; one of them was P5 from Experiment I.

Procedure

The apparatus and magazine training procedures were the same as in Experiment I. Following magazine training, each subject was exposed to daily experimental sessions identical to those of the first experiment. Following three successive sessions during which at least one key peck occurred on 90% of the S+ trials, the response-independent procedure was terminated and the negative contingency procedure for approaching toward the key was begun. Under the negative contingency procedure, the S+ was presented according to a VI 30-sec schedule (Fleshler and Hoffman, 1962). The duration of each session was increased so that 40 trials occurred within each session. Only the S+ was presented during these 40 trials. The S+ remained on for 6 sec and was followed immediately by 4 sec of access to grain if, and only if, no approach toward the key occurred during that particular trial. Whenever an intratrial approach toward the key occurred, the keylight was immediately turned off and food was not presented. The time at which trials were presented was independent of intratrial behaviors, but trial onset was delayed for 5 sec by an intertrial peck at the key.

The environmental manipulations were determined by the operations of a handswitch by the author, who viewed the behavior through the observation window of the chamber. An approach toward the key was defined as any movement that brought any part of the subject's body within the predefined front, left quarter of the chamber. The chamber was divided into quarters by the intersection of two imaginary planes lying at right angles to each other and both lying perpendicular to the floor. One plane was perpendicular to the front panel and intersected the front panel 6.35 mm to the left of the leftmost edge of the feeder aperture. The other plane ran perpendicular to the observation window and bisected that window. The front-left quarter was that part that included the area closest to the key on the left side of the chamber. If the subject were in the left quarter of the chamber at the onset of a trial, an approach toward the key was defined as the slightest detectable movement toward the key. On all trials, the occurrence of orientations to the key was observed and recorded, but this behavior had no scheduled consequences. Orientation to the key was defined as in Experiment I.

RESULTS AND DISCUSSION

Figure 2 shows the percentage of trials on which the responses of orienting to and approaching toward the key occurred within each session. For both subjects, approaches toward the key were eliminated by the negative contingency. This apparent sensitivity of approaches toward the key to their consequences was not confounded with a decrease in the functional pairings of the keylight with food, since orienting to the key did not drop out simultaneously. That is, orientations to the key may be necessary for the detection of the S+. If the decreased frequency of approaching toward the key had been accompanied by a simultaneous decrease in the frequency of orienting to the key, then the apparent effects of reinforcement upon approaches toward the key could have instead resulted from nondetection of the presence of the S+ by the subject.

The fluctuations in the percentage of trials on which at least one orientation to the key occurred for P17 were transient. Also, the number of pairings of the keylight with food presentation was inversely related to the num-
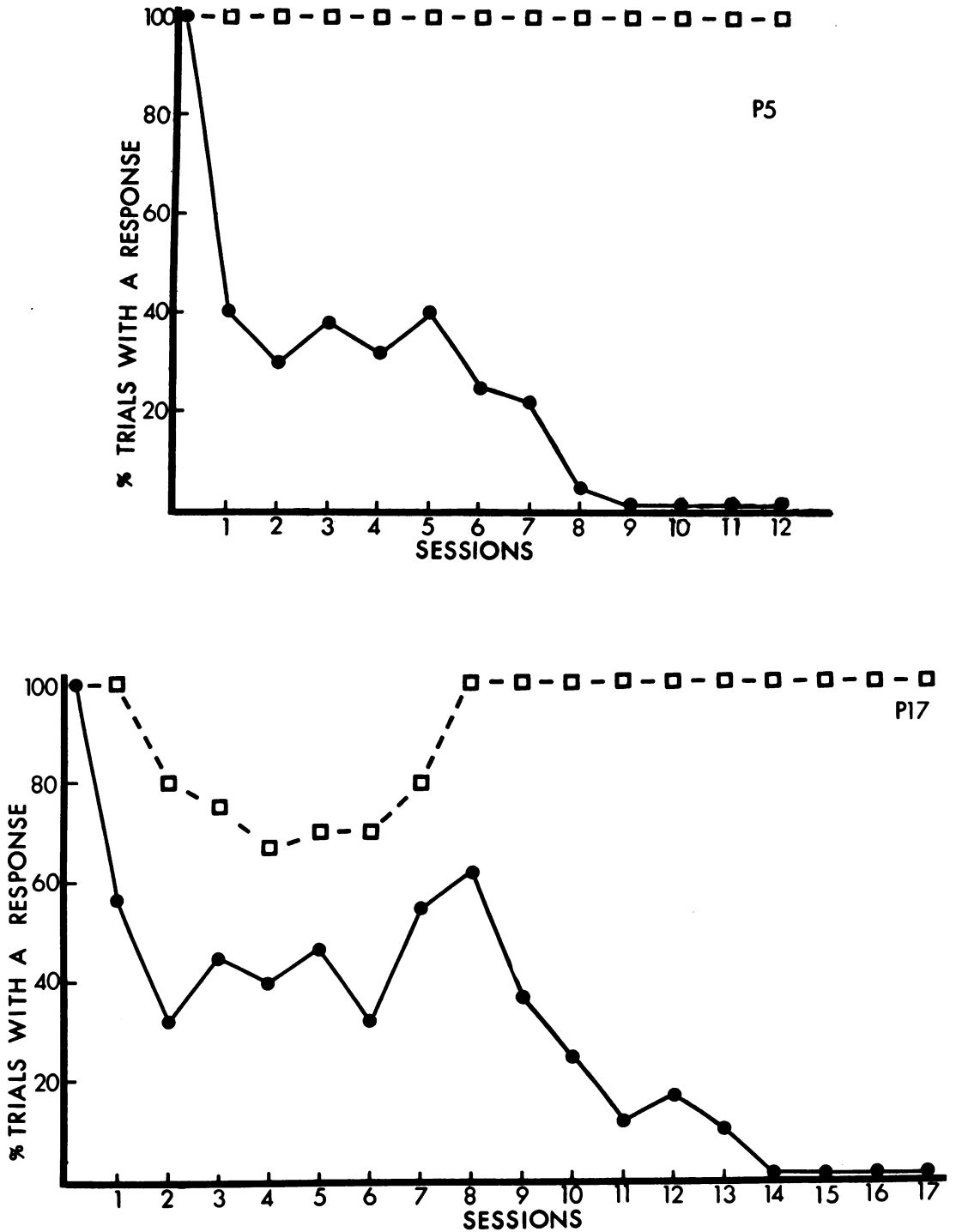
Fig. 2. The percentage of trials on which responses of orienting to the key (squares) and approaching toward the key (circles) occurred during the negative contingency for approach procedure. The first point on the graph shows the data from the last session of the response-independent procedure. Each graph is for a single subject.

ber of trials on which an approach toward the key occurred. As approaches toward the key decreased in frequency, the number and frequency of light-food pairings increased correspondingly. Since this increased number and frequency of light-food pairings did not result in a corresponding increased frequency of approaching toward the key, it may be concluded that the approaches toward the key were in fact strongly controlled by their consequences.

During the last sessions of this experiment, the intratrial behaviors of both subjects were very similar. Between trials, each subject was most frequently pacing back and forth in front of the observation window. These pacing movements were interrupted by frequent orientations to the key. A typical sequence of intratrial events was as follows. An orientation to the key was followed by locomotion to the right-front quarter of the chamber. At the front wall, the sequence of pacing along the front wall-orientation to the key occurred repeatedly until food was presented. These behaviors were highly stereotyped, and so acquisition of behaviors incompatible with approaching toward the key may be an essential condition for the effectiveness of this negative contingency procedure.

Since the approaches toward the key that result from light-food pairings are strongly affected by their consequences, an analysis of the variables that control autoshaped key pecking must consider the confounding of light-food pairings with approach-food pairings inherent in the response-independent procedure. The results of Experiment II are consistent with the finding of Schwartz and Williams (1972) that key pecks that are conditioned as a result of light-food pairings are sensitive to their consequences. Thus, it has been demonstrated that two of the responses that are conditioned in the response-independent procedure are sensitive to their consequences. It is difficult, however, to draw conclusions concerning the extent to which these responses actually are affected by reinforcement in the response-independent procedure. Future research in autoshaping might be guided most profitably by the assumption that approaches toward the key and pecks at the key are affected by the interaction of both stimulus-food pairings and response-food pairings.

EXPERIMENT III

In the response-independent procedure, the effects of stimulus-reinforcer and response-reinforcer variables are not only seriously confounded, but additionally, the locus of the effects of those variables is indeterminate, since several behaviors are conditioned. As a result, both the antecedents and the loci of stimulus control of the key peck are unclear. Although it may be necessary to perform many experiments to clarify these problems, the following preliminary experiments may help to define these problems more precisely.

In the response-independent procedure, several behaviors are conditioned and occur in the presence of a single exteroceptive stimulus. The food-paired stimulus might exert control over a directed behavior at the time of initiation of that behavior. Alternatively, stimulus control might be exerted at some point during the occurrence of an antecedent behavior. The purpose of Experiment III was to test whether the food-paired stimulus present at the time of the initiation of an approach toward the key necessarily controlled the probability of occurrence of subsequent pecks at the key. If the probability of occurrence of the key peck were determined at the time of initiation of the approach toward the key, then the subject should be insensitive to changes in the stimulus that occurred after the time of initiation of the approach toward the key. On the other hand, if the probability of occurrence of the key peck were determined by the stimulus present following the initiation of an approach toward the key, then the subject should be sensitive to stimulus changes occurring during the approach toward the key, and the effects of the stimulus change should be dependent upon the prior pairing or nonpairing of the substitute stimulus with food presentation.

METHOD

Subjects

Three experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding weights for the duration of the experiment.

Procedure

The apparatus used was the same as in the preceding experiments. Magazine training

was conducted as previously described, except that training included two additional sessions during which the average interval between successive food presentations was increased to 60 sec. The duration of food presentation was held constant at 4 sec for the entire experiment. Entrance into the left front quarter (as defined earlier) of the chamber was prohibited by the presence of a transparent barrier made of 6.35 mm Plexiglas. The placement of the Plexiglas wall required only minor modifications of the typical bodily position of a pigeon eating from the grain hopper. The wall prohibited the occurrence of complete approaches to the area directly in front of the key. Use of the wall in two previous pilot studies by the author facilitated the discrimination of effects upon approaching from those upon pecking and *vice versa*. The results of the first pilot study showed that key-directed pecks do occur in a response-independent procedure even when the wall is blocking the full approach toward the key. However, acquisition of the key peck occurred only after extended exposure to the response-independent procedure, and it did not occur in all subjects used. Since for all subjects there was a period of several sessions during which the lighted key controlled approach behavior but not pecking, no peck-food pairings and nonpairings could affect the key peck during that period.

Since the results of the second pilot study referred to above will be useful in characterizing the effects of the discrimination procedure used in Experiment III, the procedure and results of that pilot experiment are described below. The purpose of the experiment was to ascertain the effects of stimulus-food pairings and nonpairings upon approaches toward the key. The two experimentally naive White Carneaux pigeons used were prevented from entering the front-left quarter of the chamber by the Plexiglas barrier described above. The barrier was used so that the probability of occurrence of approaching toward the key could not be affected by the possible occurrence of pairings and nonpairings of pecks at the key with food presentation.

Magazine training was identical to that of Experiment III. The first five sessions following magazine training consisted of 80, 6-sec presentations of a lighted key with an average intertrial interval of 30 sec. On half of those

trials, a white light (S+) appeared on the left key and was followed immediately by food presentation. On the other half of the trials, a green light (S−) appeared on the left key and was not followed by food presentation. The sequence in which stimuli were presented was irregular and was prearranged by the use of a random numbers table. The sequence was not truly random in that no more than three successive presentations of either stimulus could occur. No behaviors of the subject had scheduled consequences.

The results of the pilot experiment are shown in Figure 3. During the initial sessions of the discrimination procedure, intratrial approaches toward the key (as defined earlier) occurred with increasing frequency in the presence of both S+ and S−. Those approaches toward the key almost invariably consisted of locomotion to the area where the Plexiglas wall intersected the front panel of the chamber. Such locomotion brought the subject as close to the key as possible under the conditions. While in that area, the subject's beak was often pointing directly towards the lighted key and head-bobbing frequently occurred. During the final sessions of the discrimination procedure, differentiation of approaches toward the key occurred. In the presence of S+, each subject approached toward the key on every trial. The number of S− trials on which an approach toward the key occurred decreased across successive blocks of S− trials. No pecks directed toward the key, the Plexiglas wall, or the magazine wall occurred. The relevance of these results to Experiment III will be clarified below.

Following magazine training, the subjects of Experiment III were exposed to five sessions (Phase I), which were with one exception identical to the five sessions of the second pilot experiment described above. In Phase I, the S+ was a green light and S− was a white light.

In the sessions following the first five, the Plexiglas wall was removed from the chamber so that the subject could approach to that area closest to the key. The first session (Phase II) following removal of the Plexiglas wall consisted of 30 presentations on the left key of a 41.0° white line on a black background. The white line stayed on for 6 sec and was followed immediately by food presentation. The average intertrial interval was 30 sec in
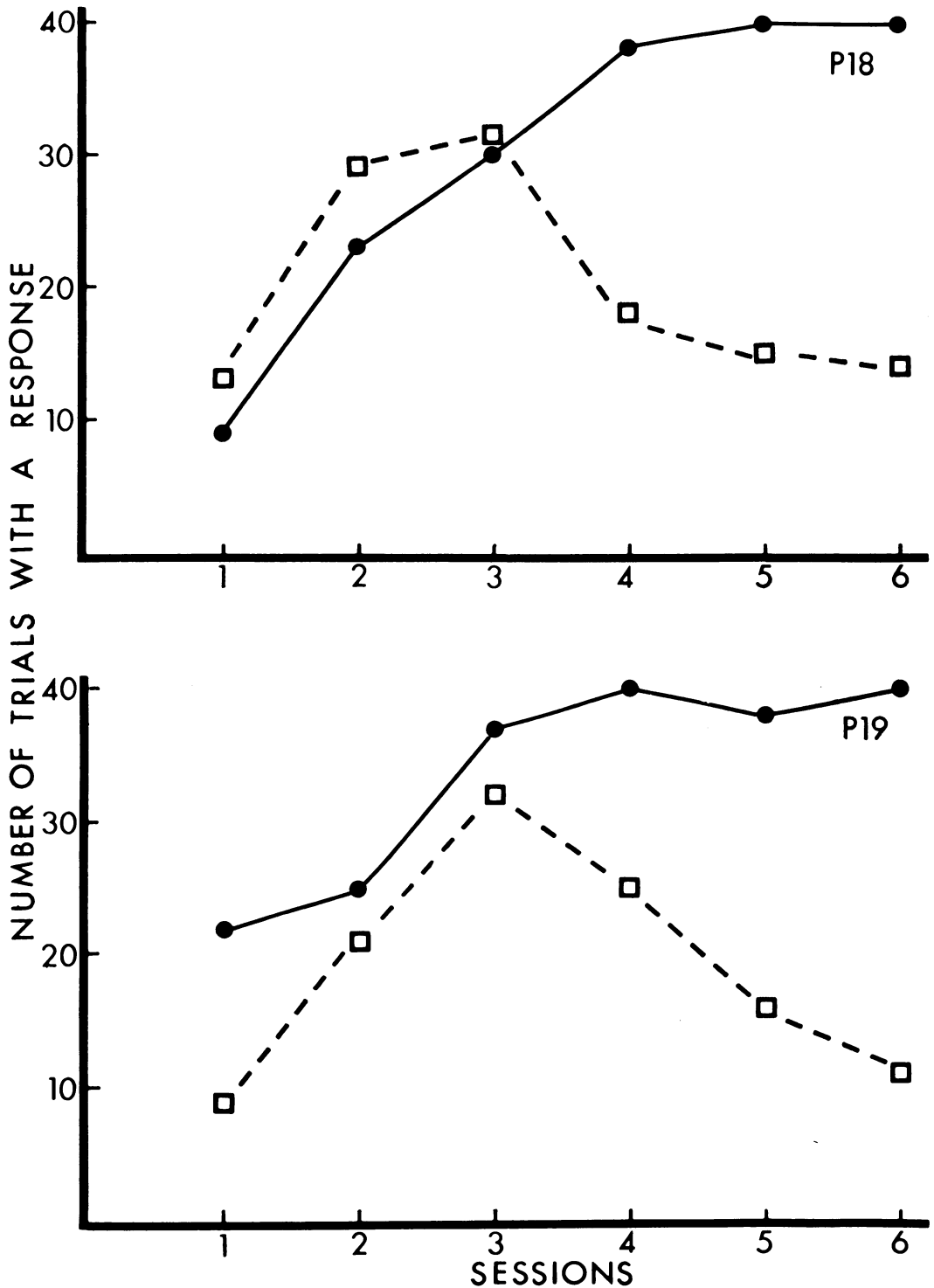
Fig. 3. The number of trials on which an approach toward the key occurred for each session of the second pilot experiment. Each session consisted of 40 S+ trials and 40 S− trials. The circles show the number of S+ trials on which an approach toward the key occurred; the squares show the number of S− trials on which an approach toward the key occurred. Each graph shows data for a single subject.

duration. All events in this phase were response-independent. The purpose of this phase was to ensure that each subject reliably approached toward and pecked at a stimulus other than those used in the preceding phase.

Following Phase II were three, 40-trial sessions (Phase III) during which three types of trial could occur. These three types are illustrated in Figure 4. Which of the three trial types occurred was partially dependent upon the occurrence of an intratrial approach toward the key. Following an average intertrial interval of 30 sec, a trial was begun by presentation of the white line on the key. If, and only if, no approach toward the key occurred in the presence of the white line, the white line was left on the key for 6 sec and was followed immediately by food presentation. But if the subject approached toward the key in the presence of the white line, the white line was immediately replaced on the key by either the S+ or the S— from Phase I. The probability of presentation of either S+ or S— was 0.50 on any trial during which an approach toward the key occurred. Their order of presentation was irregular and was prearranged by the use of a random numbers table. However, no more than three successive presentations of either stimulus could occur. Both S+ and S— were of 5-sec duration. The green light was followed immediately by the response-independent presentation of food, while the white light was never followed by food presentation.
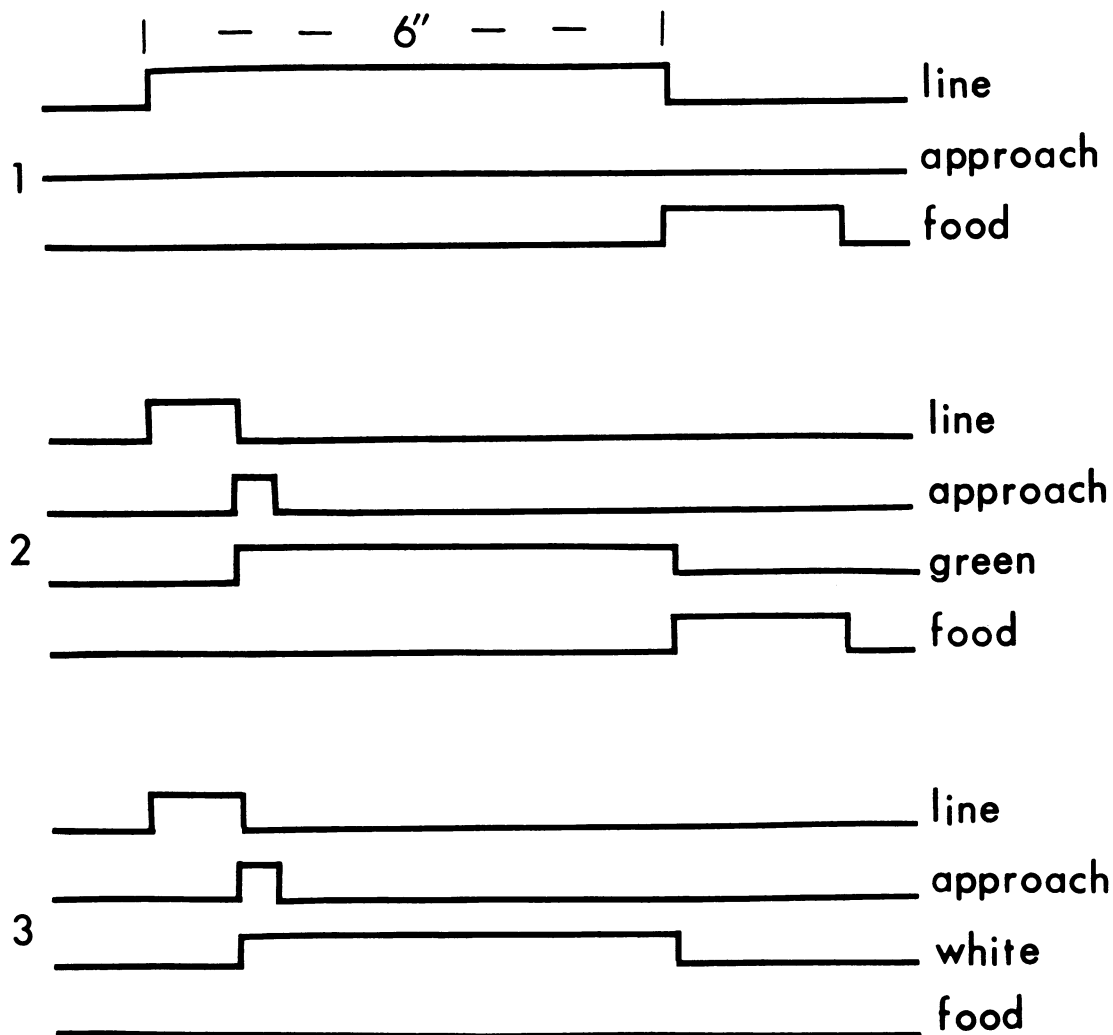

Fig. 4. The three types of trial that could occur during Phase III.

An approach toward the key was defined as before. The stimulus changes that occurred contingent upon an approach toward the key were controlled by the handswitch operations of the author. The dependent variable of primary interest in Phase III was the probability with which pecks at the key occurred in the presence of the green and white stimuli. All intratrial pecks were recorded by the author.

RESULTS AND DISCUSSION

Figure 5 shows the number of S+ and S− trials from Phase III on which at least one key peck occurred within each successive block of five S+ and S− trials, respectively, for each subject. Each subject pecked at the green stimulus upon the very first presentation of that stimulus as well as on each later presentation. Conversely, each subject halted and abruptly turned away from the key upon the very first presentation of S−, as well as on almost all subsequent S− presentations. The immediacy of the effects observed in Phase III is crucial for the interpretation of the data presented below. As Figure 5 shows, pecking occurred very infrequently in the presence of the S−, and P8 never pecked in the presence of S−.

Observation of each subject during Phase I revealed that with respect to the behavior of approaching toward the key, the behavior of the subjects of Experiment III was highly similar to that of the subjects of the second pilot experiment described above. Therefore, the differential occurrence and nonoccurrence of approaches toward the key in the presence of S+ and S− was not peculiar to some unconditioned effect of either the green or the white stimulus. As before, approaching toward the key initially increased in frequency in the presence of both S+ and S− and then subsequently decreased in the presence of S− while continuing to occur on every S+ trial. In Phase I, no subject emitted pecks directed to an area of the chamber other than the floor.

In the single session of Phase II, each subject pecked the key in the presence of the white line within the first 15 trials. Also, each subject emitted a key peck on each of the last 10 trials of the session. The facilitation of key peck acquisition which thus occurred following Phase I was probably due to the fact that the subjects were already highly controlled by stimuli presented on the key.

In Phase III, each subject approached toward the key in the presence of the white line on almost every trial. P6 and P7 approached during every trial, while P8 did not approach on the first two trials of the second session of Phase III. Since the probability of occurrence of an approach toward the key was so high in the presence of the white line, the subjects did not come into contact with the contingency, whereby non-emission of an intratrial approach toward the key was always followed by food presentation.

Even though each subject approached toward the key in the presence of the white line, the probability of occurrence of a key peck was clearly a function of the stimulus conditions that prevailed following the initiation of the approach toward the key, rather than the stimulus conditions at the time of initiation of the approach toward the key. If peck probability were determined by the stimulus conditions that prevailed at the time of initiation of the approach toward the key, then peck probability would have been the same in the presence of both S+ and S−. The effect of replacing the stimulus that controlled initiation of an approach toward the key was clearly dependent upon the prior pairing or nonpairing of the substitute stimulus with food presentation. Since the effects found in the last phase were immediate, they were not the result of effects associated with presenting stimuli from Phases II and I in a successively compound manner. The results of Experiment III are consistent with those of Experiment II in showing that the probability of occurrence of a key peck is not determined rigidly at the time of initial orientation to some food-paired stimulus. A much more extensive analysis would be needed for the precise determination of the locus of stimulus control over the key peck.

In Phase III, each subject rarely pecked in the presence of S−, while pecks in the presence of S+ occurred reliably. With respect to the key peck, the acquisition of the green-white discrimination might therefore be described as errorless. This errorless performance may have resulted from the effects of stimulus-reinforcer variables, the effects of response-reinforcer variables, or from some sort of interaction of the two types of variable. The results of many studies (see Trapold and Overmier, 1972) have shown that stimulus-reinforcer variables can exert strong discrim-
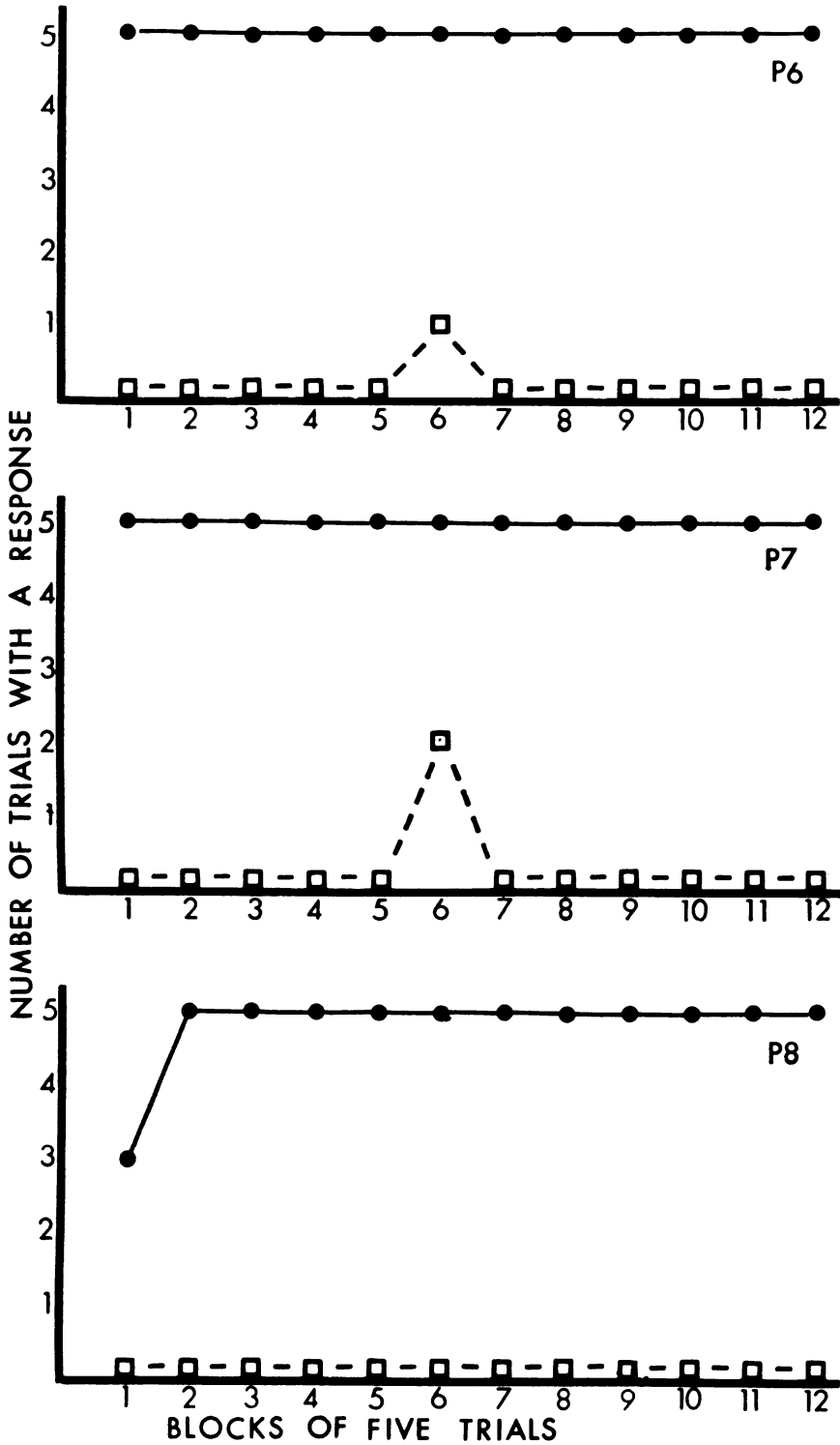
Fig. 5. The number of trials on which a key peck occurred within successive blocks of five S+ and S— trials during Phase III. Circles show the number of S+ trials on which at least one key peck occurred while the squares show the number of S— trials on which a peck occurred. Each graph shows data for a single subject.

inative control over directed skeletal behavior even when (unlike the autoshaping paradigm) no reliable pairings of response and unconditioned stimulus occur during pairings of the conditioned stimulus with the unconditioned stimulus. The errorless performance in Experiment III cannot be attributed solely to the effects of stimulus-food pairings and nonpairings, since those events were accompanied by the temporally contiguous occurrence of approaches toward the key with food presentation. It is possible that the errorless performance resulted partially from the transfer of the effects of reinforcement and nonreinforcement of approaches toward the key to the key peck. The most reasonable interpretation seems to be that the errorless performance resulted from the effects of the interaction of stimulus-food and response-food pairing factors. The nature of this interaction is unclear at present.

EXPERIMENT IV

The results of Experiment III supported the view that the probability of occurrence of pecks at the key is affected during the occurrence of the approach toward the key by the presence of stimuli that were either paired or nonpaired with food presentation. The antecedents of the stimulus control of pecking the key exerted by S+ and S— of Experiment III are ambiguous; the effects of stimulus-food pairings and nonpairings were confounded with the effects of unscheduled but reliably occurring pairings and nonpairings of approaches toward the key with food presentation. The purpose of Experiment IV was to determine whether the effects of the stimulus present during an approach toward the key could be attributed solely to stimulus-food pairings and nonpairings. In Experiment IV, a negative contingency procedure similar to that of Experiment II was used to produce a stimulus in whose presence approaches toward the key did not occur despite consistent pairings of that stimulus with food presentation. If the presence of such a stimulus during an approach toward the key resulted in a low probability of occurrence of pecks at the key, it could be concluded that pairings and nonpairings of approaches toward the key with food presentation were also important in the discriminative control of the key peck.

METHOD

Subjects

Two experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding weights.

Procedure

The apparatus used was the same as that of the preceding experiments. Magazine training was conducted as it was in the third experiment. During each of the first two sessions following magazine training, 40 response-independent pairings of a white keylight with food presentation were given. The white light was the same stimulus used in Experiment III and it was 6 sec in duration. The purpose of these two sessions was to provide a baseline of autoshaped approaching and pecking against which the effectiveness of the subsequent negative contingency could be assessed.

In Session 3, a negative contingency procedure for approaching toward the key was begun. The response of approaching toward the key was defined as before. A fading technique was used in an attempt to speed the course of acquisition during the negative contingency procedure. The fading technique consisted of presenting the white light for 2.0 sec during the early presentations of that stimulus and then progressively increasing the duration of that stimulus to its final value over subsequent sessions. In Session 3, the white light was presented 40 times according to a VI 30-sec schedule (Fleshler and Hoffman, 1962). If no approach toward the key occurred, the key remained lighted for 2.0 sec and was followed by food presentation. The occurrence of an intratrial approach toward the key was followed immediately by the offset of the keylight and food was not presented for that trial. As in the following sessions, the subject's intratrial behavior had no effect on the time of occurrence of subsequent trials. Pecks on the key during the intertrial interval postponed the presentation of the next trial by 5 sec.

In Session 4, discrimination training was begun. Each discrimination session consisted of a total of 40 trials of two kinds. On one type of trial, the 41.0° white line on a black background (identical to that used in the second phase of Experiment III) was presented for 6 sec and was paired response-inde-

pendently with food presentation. The second type of trial consisted of presenting the white light for 2.0 sec with the negative contingency for approaching toward the key in effect. The two types of trial occurred successively and occurred in an irregular sequence. In an attempt to hasten acquisition of stimulus control, only one of every five trials on the average was a response-independent trial. The intertrial interval was the same as in the preceding sessions. Pecks on the key during the intertrial interval postponed the onset of the next trial by 5 sec.

Over the subsequent discrimination sessions, the duration of the white light on negative contingency trials was gradually increased to its final value of 5.0 sec according to the following schedule. During Session n, if the subject did not approach toward the key on 85% of the negative contingency trials, then the duration of the white light was increased by 0.5 sec for Session n + 1. If the subject approached toward the key on more than 15% of the negative contingency trials during Sessions n + 1 and n + 2, then the duration of the white light was decreased by 0.5 sec for Session n + 3.

Discrimination training continued until the discrimination performance of the subject was perfect for three successive sessions, during which the duration of the white light was at its final value. The criteria according to which discrimination performance was defined as perfect were (1) the occurrence of at least one key peck on each response-independent trial and (2) the absence of an approach toward the key on each negative contingency trial. The purpose of the discrimination procedure was to ensure first that the white line controlled the sequence of directed behaviors described in Experiment I and secondly, that approaches toward the key did not occur in the presence of the white light, even though that stimulus was consistently paired with food presentation. This discrimination procedure was used because it had been observed in a pilot experiment that the negative contingency procedure described above deterred acquisition of approaching toward and pecking at a second stimulus that was response-independently paired with food presentation. The negative contingency procedure interfered with acquisition only if the negative contingency strongly controlled the subject's

behavior before the response-independent pairings of the second stimulus with food. To avoid that problem, the discrimination procedure of Experiment IV involved presenting the white line before the time at which the negative contingency strongly controlled the behavior of the subject.

A single test session occurred immediately following the three discrimination sessions in which the discrimination performance of the subject was perfect. The test session consisted of a total of 40 trials. Trials occurred according to the same VI 30-sec schedule used before. If a peck at the key occurred between trials, the onset of the next trial was delayed by 5 sec. Two types of trial were possible. Each trial began when the white line was presented on the key. If no approach toward the key occurred, the white line remained on the key for 6 sec and was followed by food presentation. If the subject approached toward the key in the presence of the white line, the white line was immediately replaced by the white light in the presence of which the negative contingency had previously been in effect. The white light remained on the key for 5 sec and was always paired response-independently with food presentation. The intratrial stimulus change that occurred contingent upon the occurrence of an approach toward the key was controlled by the handswitch operations of the author. The dependent variable of primary interest was the probability with which pecking at the key occurred in the presence of the white light.

RESULTS AND DISCUSSION

During the two sessions when the white light was paired response-independently with food presentation, acquisition of the key peck occurred for each subject. For P1, at least one peck at the key occurred on every trial after trial 63. P2 pecked at the key at least once on each trial following trial 46.

The results of the discrimination training are shown in Table 2. For each subject, the fading procedure was highly effective in eliminating approaches toward the key in the presence of the white light. In the final discrimination sessions, the behavior of both birds was similar to that of the subjects observed in the terminal portion of Experiment II. The rapidity with which approaches toward the key were eliminated may have resulted from

the very rapid acquisition of stereotyped intra-trial behaviors similar to those noted in Experiment II. In Experiment II, stereotyped behavior patterns did not occur reliably during the first seven sessions for either subject. In the present experiment, stereotyped behaviors reliably occurred while the duration of the white light was only 2.0 sec. Table 2 shows that as approaches toward the key decreased in frequency, orientations toward the key continued to occur on each trial. Since intratrial approaches toward the key did not occur during the last three sessions of the discrimination procedure, the white light was paired with food presentation each time it was presented.

During the discrimination procedure, both subjects pecked at the key in the presence of the white line within the first 10 presentations of that stimulus. Such rapid acquisition may have resulted from the fact that the behavior of the subject was controlled by the stimulus presented on the key even before the white line was introduced. Over sessions of discrimination training, orientations to, approaches toward, and pecks at the key occurred with increasing probability in the presence of the white line. Although the stimuli used did interact to the extent noted below, the interactions were not sufficiently strong to overcome the effectiveness of the discrimination procedure. During the early sessions of dis-

crimination training, both P1 and P2 sometimes failed to approach toward the key immediately when the white line was presented. Instead, they behaved in the presence of the white line as they did in the presence of the white light. On occasion, the behaviors usually controlled by the white light continued throughout the trial and were followed by food presentation. At other times, those behaviors occurred only in the early part of the trial and were soon followed by an approach toward the key and pecks at the key.

The results of the test session were unambiguous for both subjects. Each subject approached toward the key in the presence of the white line upon each trial, but each halted abruptly upon the very first and all later presentations of the white light. No pecks at the key occurred on any of the 40 test trials for either subject. When the white light was presented, each subject immediately engaged in the same stereotyped behaviors that were controlled by the white light before the test session.

The results of the experiment show that the effects of a stimulus present during an approach toward the key cannot be attributed solely to the effects of consistently pairing that stimulus with food presentation. It is unclear as to the extent to which the results of Experiment IV are dependent upon the reliable occurrence of the observed, stereotyped behav-

Table 2

Table 2 shows the discrimination performance of each subject within each discrimination session. Column I shows the duration (seconds) of the white light in whose presence the negative contingency was in effect for each session. Column II shows the mean percentage of negative contingency trials during which at least one orientation to the key occurred. Column III shows the mean percentage of negative contingency trials during which no approach toward the key occurred. Column IV shows the mean percentage of response-independent trials during which at least one peck at the key occurred.

Discrimination Session	P1				Discrimination Session	P2			
	I	II	III	IV		I	II	III	IV
1	2.0	100	18	12	1	2.0	100	51	22
2	2.0	100	75	57	2	2.0	100	90	66
3	2.0	100	90	75	3	2.5	100	90	90
4	2.5	100	87	100	4	3.0	100	96	100
5	3.0	100	77	100	5	3.5	100	100	75
6	3.0	100	88	100	6	4.0	100	96	100
7	3.5	100	96	100	7	4.5	100	100	100
8	4.0	100	96	100	8	5.0	100	100	100
9	4.5	100	96	100	9	5.0	100	100	100
10	5.0	100	100	100	10	5.0	100	100	100
11	5.0	100	100	100					
12	5.0	100	100	100					

iors that were controlled by the presence of
the white light. Information concerning the
latter consideration is not, however, relevant
to the conclusion of the experiment. It is also
unclear as to the extent to which approach-
food pairings and nonpairings affect the prob-
ability of occurrence of the key peck in the
presence of a food-paired stimulus. This prob-
lem can be clarified only by further experi-
mentation.

GENERAL DISCUSSION

The results of the present experiments show
that there is a serious confounding of stim-
ulus-reinforcer and response-reinforcer vari-
ables in the response-independent procedure.
The experimental manipulation of stimulus-
food pairings and nonpairings may simulta-
neously produce a shift in unscheduled but
reliably occurring response-food pairings and
nonpairings. The existence of this confound-
ing makes it difficult to ascertain the direct
effects of stimulus-food pairings upon a re-
sponse such as the key peck. For example,
Williams and Williams (1969) showed that the
pecking that results from repeated light-food
pairings continues to occur even when the
pecking results in nonreinforcement. Since the
pecking that occurred in that situation was
never followed by food presentation, adventi-
tious reinforcement of pecking could not have
occurred. However, it would be premature to
attribute the occurrence of pecking in the
negative automaintenance paradigm solely to
the direct effects of intermittent light-food
pairings. Negatively automaintained pecking
could have resulted partially from the effects
of reinforcement upon directed behaviors oc-
curring antecedent to the key peck.

The results of the experiments described
above suggest that the key-directed behaviors
that are conditioned in the response-indepen-
dent procedure are affected by the interaction
of stimulus-reinforcer variables and response-
reinforcer variables both before and after ac-
quisition of the key peck. For example, the re-
sults of Experiments III and IV show that
the probability of occurrence of the key peck
in the presence of the stimulus on the key dur-
ing the approach toward the key is to some ex-
tent dependent upon the prior occurrence of
approach-food pairings in the presence of that
stimulus. Williams and Williams (1969), how-

ever, showed that adventitious reinforcement
of nonpecking behaviors could not by itself
account for the pecking that results from
light-food pairings. Clearly, acquisition of the
key peck must result in part from the effects
of variational factors (Staddon and Simmel-
hag, 1971) in the response-independent pro-
cedure. Both the extent and the precise nature
of the interaction of stimulus-reinforcer and
response-reinforcer variables are unknown at
present. The failure to consider the fact that
these variables may interact even before ac-
quisition of the key peck will most likely act
to hinder the formulation of a comprehensive
account of the autoshaping phenomenon.

The responses of approaching toward and
pecking at the key may be described as non-
independent, to the extent that the effects of
pairing or nonpairing one of those responses
with food simultaneously affects the probabil-
ity of occurrence of the other response. The
nonindependence of those responses is hardly
a novel phenomenon; it is taken advantage of
when the pecking response is shaped through
successive approximations. Little is known
concerning the conditions under which ap-
proaching and pecking (or any other pair of
topographically distinct responses, for that
matter) are nonindependent. The results of
Experiments III and IV suggest that ap-
proaching and pecking are nonindependent
when one of those responses is followed by
food presentation in the presence of a food-
paired stimulus. It is not contended here that
the demonstrated nonindependence of ap-
proaching and pecking is an unmodifiable
feature of the pigeon's behavior. It may be
possible to arrange conditions under which re-
inforcement of an approach response has no
effects on the probability with which the peck-
ing response occurs.

Some speculations concerning the feeding
behavior of the pigeon may help to clarify the
antecedents and the nature of the nonindepen-
dence of approaching and pecking described
above. First, assume that the pigeon must
orient to, approach toward, and peck at local-
ized, food-paired stimuli in order for food in-
gestion to occur. Although the author knows
of no detailed description of the species-
typical sequence of feeding behaviors of the
pigeon, orienting to and approaching toward
grain have been observed in this labora-
tory to precede pecking at grain both reliably

and frequently. When orientations to and approaches toward a food-paired stimulus precede the occurrence of successful pecks at the food-paired stimulus, all three responses are followed by food ingestion in the presence of the same localized stimulus. Perhaps a feeding history of this sort is sufficient to establish a relation of nonindependence between the approaching and pecking components of the sequence of feeding behaviors.

The general problem of the nature and extent of nonindependence of different behaviors deserves careful investigation in the future. The analysis of that problem might not only help to clarify the effects of approach-food pairings in the response-independent procedure, but also would help to define the more general problem of the conditions under which topographically distinct responses are affected simultaneously by the same set of environmental events. Such an analysis might elucidate the conditions under which different responses function as members of a single operant, and it might help to place such anomalous findings as those of Breland and Breland (1961) in a systematic perspective.

Here is a speculative but plausible account of autoshaping, one that includes the effects of both stimulus-reinforcer variables and response-reinforcer variables upon both pecking and nonpecking behaviors. Orientation to the lighted key is directly engendered by repeated and differential light-food pairings. Light-food pairings also act directly to increase the probability of an approach toward the key. The probability of approaching toward the key is also increased by the pairings of orientations to the key with food presentation. Once the responses of orienting and approaching have been conditioned, both responses are followed by food ingestion, even though no pecks at the key have occurred. The repeated light-food pairings, in conjunction with the repeated pairing of orientations to and approaches toward the key with food presentation, act to increase the probability of occurrence of pecks at the key. Once the peck occurs, it too is paired with food presentation and so the future probability of occurrence of a peck is increased.

This account of autoshaping is consistent with the results of the experiments described above, but it is not necessitated by those results. Both previous findings (Schwartz and

Williams, 1972) and those described above show that the responses conditioned in the response-independent procedure can be affected by their consequences. It remains the task of future research to determine how stimulus-food pairings affect the directed skeletal behavior that occurs in the response-independent procedure. They may do so in several ways. First, they may affect skeletal behavior primarily through direct effects. Second, they may affect a behavior indirectly by either providing or not providing the conditions under which adventitious reinforcement can occur. More specifically, stimulus-food pairings and nonpairings may affect a behavior indirectly by directly changing the frequency of occurrence of either that behavior or a nonindependent, antecedent behavior that can (or cannot) then be affected by reinforcement. Third, stimulus-food pairings may affect skeletal behaviors both directly and indirectly. The latter alternative is preferred here because it takes into account the effects of both stimulus-reinforcer and response-reinforcer variables upon pecking and nonpecking behaviors.

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