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TRANSFER OF CONTROL OF THE PIGEON'S KEY PECK FROM FOOD REINFORCEMENT TO AVOIDANCE OF SHOCK

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Eight pigeons were initially trained to peck a white key for food under a variable-interval 1-min schedule of reinforcement. Then, a shock-avoidance schedule was initiated and food was no longer available in the experimental situation. Under the avoidance schedule, each peck on the key postponed shock for 40 sec. A warning signal, consisting of tone and red houselights, was presented after 30 sec without a response. If no response occurred, a shock was delivered 10 sec after warning-signal onset. Shocks were delivered every 10 sec in the presence of the warning signal until a response was made. The warning signal was terminated only by a response. Key pecking of all eight pigeons came under control of the avoidance schedule and responding continued throughout the 20-day avoidance training period.

Although the pigeon has been the subject of considerable psychological research in which responding has been controlled by positive reinforcement, there have been relatively few reports of avoidance responding using this species. Recently, success has been reported in training a variety of avoidance responses, including head lifting (Hoffman and Fleshler, 1959), general activity (Graf and Bitterman, 1963), running (Macphail, 1968), and treadle pressing (Dinsmoor and Sears, 1973; Foree and LoLordo, 1970; Klein and Rilling, 1972; Leander and Jowaisis, 1972; Smith and Keller, 1970). Since the vast majority of experiments using positive reinforcement with pigeons employ the key-peck response, however, it seems appropriate for the purposes of comparison to develop techniques for training this response as an avoidance response, too.

Rachlin and Hineline (1967) described a procedure in which birds could be trained to peck a key to escape a train of shocks delivered at a frequency of one shock every 0.5 sec and that gradually increased in intensity from 0 to 8.7 mA. In an extension of this work (Hineline and Rachlin, 1969), the procedure was modified to resemble a standard discriminated avoidance procedure. After the response key was illuminated, the occurrence of a peck within a 25-sec "trial" interval produced a blackout and the next cycle. If no peck occurred within 25 sec, a train of very intense shocks was introduced, and a peck was required to terminate it and produce a blackout period. One bird achieved 90% avoidances, another 30% to 70%, and a third reverted to escape responding after making some avoidance responses early in training.

Recently, Ferrari, Todorov, and Graeff (1973) used a procedure in which four birds were hand-shaped to peck an illuminated key in a chamber that was otherwise dark. In the shaping procedure, both the frequency and the intensity of shock were varied in accordance with the bird's behavior. For instance, attempts to escape through the Plexiglas front of the experimental chamber were followed by shocks of maximal intensity, whereas movements away from the window and towards the key were followed by reduction in the shock intensity, or if the approximation of key pecking was close enough, by a 15-sec shock-free period. All four birds acquired the key peck after several hours of shaping.

Several investigators (*e.g.*, Bolles, 1970; Ferrari *et al.*, 1973; Seligman, 1970; Shettle-

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worth, 1972; Smith, Gustavson, and Gregor, 1972) have suggested that the difficulty encountered in training birds to peck a key in order to avoid shock may be attributed to the low probability of occurrence of key pecks in any situation in which the bird is receiving intense shocks. The responses elicited by shock seem to be incompatible with key pecking (Smith *et al.,* 1972). Difficulties similar in kind but not in degree have also been encountered when training rats to press a bar to avoid shocks (see D'Amato and Schiff, 1964; Feldman and Bremner, 1963; Hoffman, 1966; and Meyer, Cho, and Weseman, 1960). Three recent reports (Giulian and Schmaltz, 1973; Kulkarni and Job, 1970; Riess, 1970) have shown that for rats, the difficulties may be overcome by first training the bar-press response by use of positive reinforcement and then altering the situation in such a way that responses avoided shock. The present experiment employed a similar strategy to condition efficient discriminated key-peck avoidance in pigeons.

METHOD

Subjects

Eight adult male White Carneaux pigeons were implanted with stainless steel pubis electrodes that were connected to a double banana plug. The banana plug was attached to a leather harness worn by the bird at all times. (Azrin, 1959; Coughlin, 1970). The birds were maintained at 80% of their free-feeding weights until after the first avoidance session. Subsequently, their daily ration of food was increased so that they rapidly gained weight. After approximately one week on the increased ration, the birds were given free access to food in the home cage for the remainder of the experiment. Water and grit were freely available in the individual home cages, which were in a common colony room.

Four birds (389, 972, 975, and 978) had previously been in experiments in which they had pecked a key for food and concurrently had depressed a foot treadle either to avoid electric shock (for 978) in a signalled free-operant procedure or to avoid a punishment contingency for key pecking. These four birds had initially been trained to peck the key by use of an autoshaping procedure (Brown and Jenkins, 1968). The remaining four birds had not pecked a key before the present experiment. Birds 382 and 383 previously had been in an experiment investigating the effects of signal-shock pairings upon treadle pressing maintained by food delivery. The remaining two birds, 988 and 395, were experimentally naive. All of the birds with experimental histories had been trained in an experimental chamber other than the one used in the present experiment.

Apparatus

The experimental chamber was a sound-attenuating, ventilated 29- by 39- by 28-cm box. Three walls were of wood painted white. One white wall contained a 6-cm diameter round observation window of half-aluminized plastic film, and the opposite wall contained a loudspeaker through which a 440-Hz tone could be delivered. The tone increased the sound level in the box to 84 dB from an ambient level of 80 dB. The fourth wall was black and contained a 5- by 6-cm opening through which grain could be presented. Above the grain magazine was a 2-cm diameter Lehigh Valley pigeon key that could be illuminated by white light. The key, which was mounted 21 cm above the floor, was recessed 0.9 cm from the inside surface of the wall. A force of about 0.15 N was required for its operation. The floor was of 1-cm square hardware cloth and the ceiling was of white translucent Plexiglas above which were four 110-V red 7-W lights and one 2.8-W, 28-V white light.

The shock source was 60 Hz, 110 V ac transformed via a variable transformer and then passed through a 10K-ohm resistor. Shock was transmitted via a cable that swivelled at one end in the center of the ceiling and was connected at the other end to the banana plug on the bird's harness immediately before a session.

The experiment was controlled by electromechanical scheduling equipment in an adjacent room.

Procedure

Initial key-peck training. Birds 389, 972, 975, and 978 had been trained to peck a white key under a variable-interval schedule of food reinforcement in another chamber. These birds received three daily 1-hr sessions of key-peck training under a variable-interval 1-min (VI 1-min) schedule of reinforcement in the apparatus used in the present experiment.

The remaining birds were hand-shaped to peck the key for access to grain and then reinforced on a VI 10-sec, a VI 30-sec, and finally a VI 1-min schedule of reinforcement. A total of nine days of positively reinforced key-peck training was given to each of these birds, with at least the final five days of training being under the VI 1-min schedule. Reinforcement consisted of 5-sec access to grain in a chamber darkened except for the feeder light. Except during reinforcement, the white houselight was on at all times during the session and the key was illuminated with white light. No feedback other than the click of the microswitch behind the response key and the aperiodic delivery of food was contingent upon key pecks.

Avoidance training. Beginning with the first avoidance day, food was never again available during the experimental sessions. On the first avoidance day, the session was begun with the stimulus conditions exactly as those used in the key-peck training phase. The avoidance schedule was initiated by the bird's first peck on the white key. This and each subsequent peck in the presence of the white houselight postponed the occurrence of shock by 40 sec. Feedback for pecks in the white houselight condition consisted of turning off the houselight and the keylight briefly (about 150 msec). A warning stimulus, consisting of a tone and the red houselights, was presented when 30 sec elapsed with no key peck being emitted. A response in the presence of the warning signal reinstated the conditions of white houselight and no tone and postponed shock for 40 sec. A failure to respond within 10 sec after signal onset resulted in a brief (175-msec) shock. The warning signal remained on with a shock being delivered every 10 sec until a key-peck response was made.

The variable transformer that controlled shock intensity was set at 30 V for the first avoidance session, and intensity was increased daily by 5-V increments to 50 V, where it remained until the 20-session training period was completed. This range of intensities is about 3 to 5 mA.

For one bird (975), very few avoidance responses had been made by Session 4, so a brief period of hand-shaping was instituted. Successive approximations to key pecks were reinforced by removing the warning signal and presenting the safety signal. After 10 such reinforcements key-pecking began.

RESULTS

For seven of the eight subjects, the key-peck response rapidly came under control of the shock-avoidance schedule. The eighth bird, 975, began to peck after 10 reinforced approximations to key pecks. All microswitch closures that occurred during aperiodic observations of the birds were produced by pecks on the key and not wing flaps (see Rachlin, 1969).

Figure 1 illustrates the development of avoidance responding for Bird 978. Panel I, Figure 1 shows the final day of key-peck responding under the VI 1-min schedule of positive reinforcement. The oblique pips of the response pen indicate food delivery. Panels II, III, IV, and V show the first, second, third, and twentieth sessions, respectively, of signalled avoidance. In these panels, oblique pips of the response pen indicate shock delivery. Downward deflections of the lower pen indicate signal onset. The avoidance schedule began with the first key peck in panel II. Pecking was maintained to point A by the history of positive reinforcement for key pecking. At A, the bird first paused for over 30 sec and the warning signal was introduced. Forty-one shocks were delivered between A and B, at which point a single key peck reinstated the safety signal of white houselight and no tone and postponed the next shock by 40 sec. Once at C and four times at D the bird pecked the key in the presence of the warning signal but before shock delivery. The second avoidance session, as shown in panel III, began with a period of about 4 min during which key pecking occurred at a rate high enough to postpone signal onset and shock delivery. By the middle of this session, however, the rate of responding dropped and responding came under the control of the warning signal. Few responses were made in the absence of the signal, yet the signal was usually terminated by a response before shock delivery. The two remaining panels show for avoidance Sessions 3 and 20 the characteristic response pattern consisting of a warmup period early in the session, during which several shocks were received, followed by responding at a steady low rate sufficient to avoid most shocks.

The development of control over responding by the avoidance schedule shown in Figure 1 was typical of six of the eight birds. Bird 975 required a short period of hand-shaping

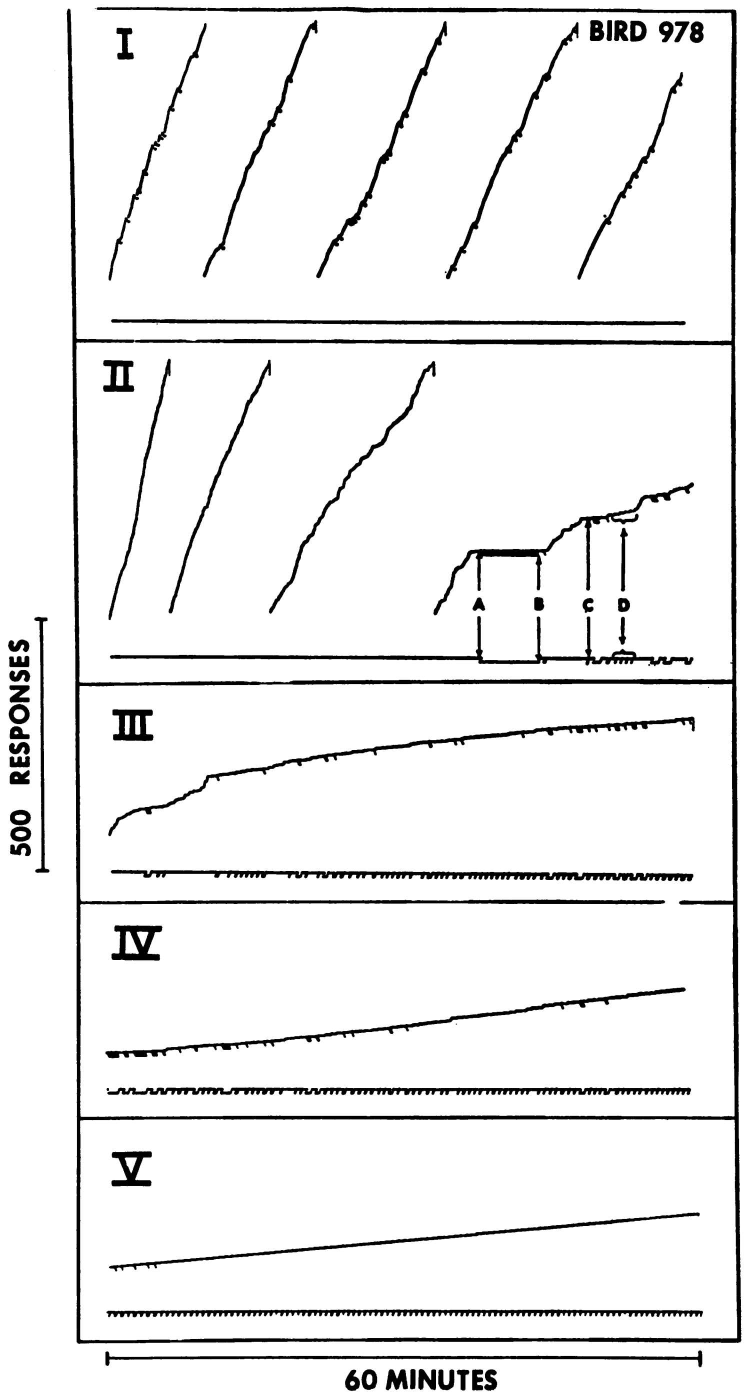

Fig. 1. Cumulative records showing the development of transfer of control of key pecking from food reinforcement to avoidance of shock for Bird 978. Panel I shows the final day of training on a VI 1-min schedule of food reinforcement. Panels II through V show the first, second, third, and twentieth avoidance sessions respectively. Oblique pips of the response pen indicate food delivery in panel I and shock delivery in panels II through V. Downward deflection of the lower pen indicates presence of the warning signal. Between points A and B of panel II, 41 shocks were delivered. Once at C and four times at D a response was made in the warning signal before shock delivery.

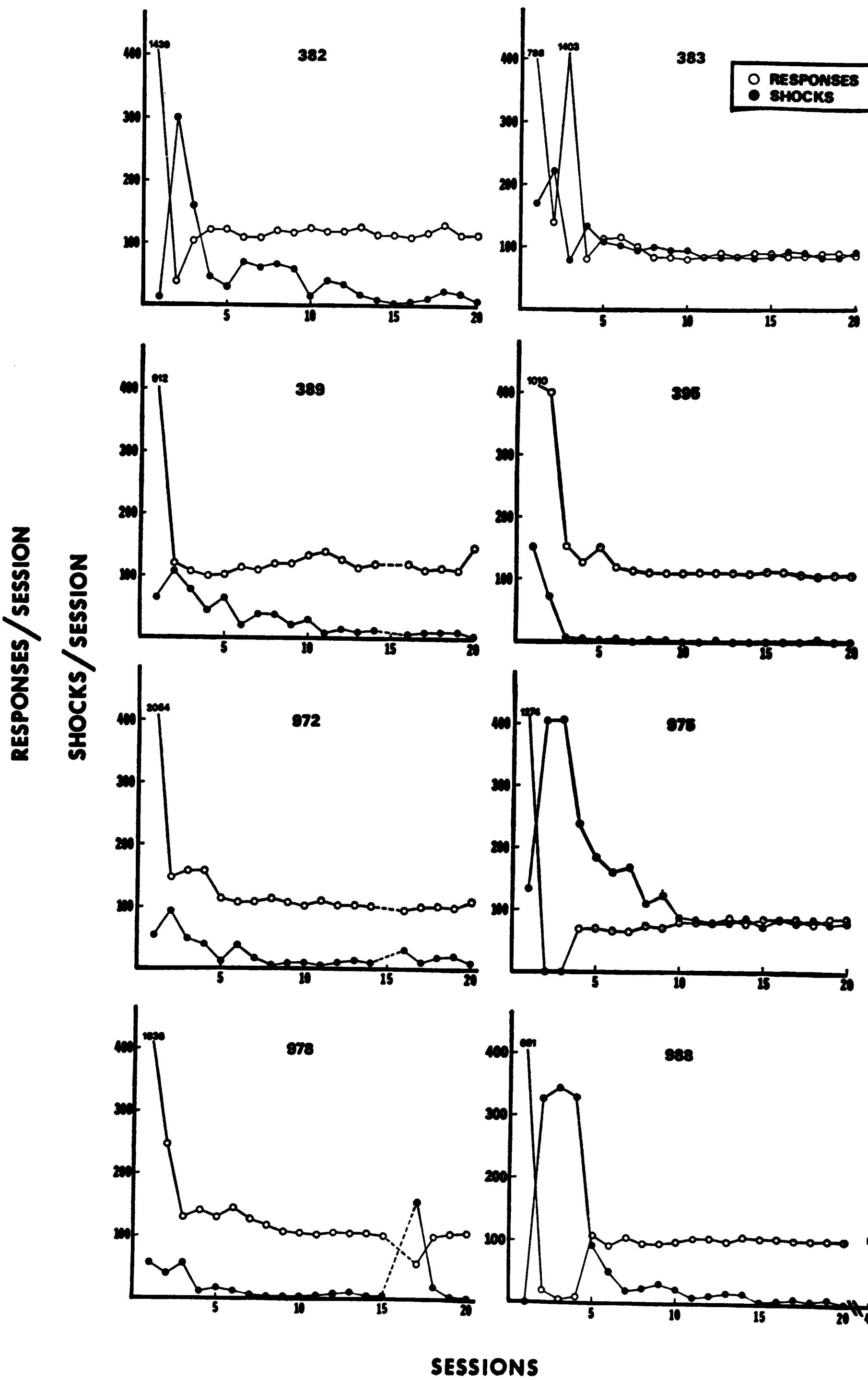

Fig. 2. Number of responses made (open circles) and number of shocks received (filled circles) per session for each of eight birds across 20 avoidance sessions. For Bird 988 (lower right-hand panel), the number of responses and shocks during Session 48 are also shown as open and filled squares respectively. The scale has been truncated at 400 per session for clarity; the small numbers at the top left of each panel indicate the number of responses made during sessions where this number exceeds the limits of the scale used.

in its fourth avoidance session before it began to respond. This bird and Bird 383 never developed the pattern of responding before shock delivery in the presence of the warning signal. Their behavior could better be described as escape from a stimulus correlated with occasional brief shocks. After a warmup period of about 5 min, these birds almost always responded immediately after receiving a single shock. Only rarely did they respond to the signal before shock delivery.

Figure 2 shows response rates and shock rates for the individual subjects over the 20-session avoidance training period. The point that has been left out near Session 15 for some birds represents a special session in which the warning signal was altered in various ways. These data will not be discussed here, but one of the results of the manipulation was that most birds received many more than the usual number of shocks during that session. For all birds but 978, responding during the following session was near normal. Bird 978 received many shocks and responded less than usual in the session following the manipulation, but recovered almost completely by the succeeding session.

As illustrated in Figure 2, shock rates and response rates quickly reached an asymptotic level and remained relatively stable until the end of the 20-session training period. For most birds, the schedule was changed on Day 21, but Bird 988 received an additional 28 days of training under the schedule described in this report. Shock rate and response rate for the final day of training for this bird are shown as filled and open squares respectively in Figure 2.

With the parameters used in this study, a bird would receive about 100 trials per session. It may be seen from Figure 2 that for all eight birds, about 100 responses per session were emitted. Responses in the absence of the warning signal were very rare, as were "bursts" of responding to terminate the signal. Figure 3, which depicts an interresponse-time distribution from the forty-eighth avoidance session of Bird 988, illustrates the pattern of responding noted for most birds. During this session, Bird 988 made no responses in the absence of the signal, so all of the presignal time has been compressed into a single time bin. The two birds that did not show this pattern of responding (383 and 975) made virtually all of their responses within 2 sec after shock delivery.

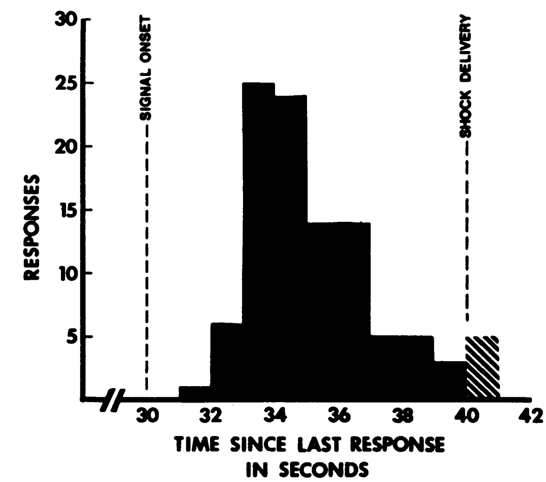

Fig. 3. Interresponse-time distribution obtained during Session 48 of Bird 988. Since no responses occurred in the absence of the warning signal, the abscissa has been foreshortened. Solid bars indicate responses made in the signal and before shock; the oblique striped bar indicates responses following shock.

DISCUSSION

When the initial probability of key pecking had first been increased through a procedure involving positive reinforcement of that response, pigeons were reliably and rapidly trained to peck a key to avoid electric shock in a signalled free-operant avoidance situation. Six of the eight birds, including the two naive birds, made almost all of their responses in the presence of the signal and before shock delivery. This is the same pattern of responding noted in rats performing a lever-press response (Ulrich, Holz, and Azrin, 1964) and in pigeons performing a treadle-press response (Foree and LoLordo, 1970) under similar avoidance schedules.

The remaining two birds responded almost exclusively after receiving a shock. This pattern also has been noted previously for rats in a lever-press situation (Ellen and Wilson, 1964) and for pigeons in a treadle-press situation (Foree and LoLordo, 1970). The patterns of responding noted in the present experiment differ from those noted for pigeon subjects using a treadle-press response (Foree and LoLordo, 1970), primarily in that response "burst", which were often initiated with a successful avoidance response in the treadle-press situation, were almost never noted with the key-peck response.

The present results are consonant with those obtained with rats by Giulian and Schmaltz (1973), Kulkarni and Job (1970), and Riess (1970). In all of these studies, rapid and efficient bar-press avoidance was established in rats by first increasing the probability of the response through positive reinforcement and then initiating a shock-avoidance schedule. The present results do not agree, however, with those of Schwartz and Coulter (1973), who reported a failure of transfer of control of key pecking in pigeons from food reinforcement to the avoidance of electric shock. The experiment by Schwartz and Coulter and the present one are similar in that both used pigeon subjects and a key-peck response. In addition, the apparatus used by Schwartz and Coulter seems not to differ in important respects from the present one, other than in the shock source and shock delivery system (implanted pubis electrodes in the present case and wire wing-band electrodes in the case of Schwartz and Coulter).

Several procedural differences between the two experiments, however, may have contributed to the quite different results obtained. First, Schwartz and Coulter employed a modified escape-avoidance paradigm in which a shock of relatively low intensity (1.3 mA) came on 7.5 sec after a warning signal had been introduced, and remained on for a maximum of 6 sec, at which time both shock and signal were turned off. Trials were presented on a variable-time 50-sec (VT 50-sec) schedule and intertrial responses had no scheduled consequence. In the present experiment, brief but relatively intense shocks (about 3 to 5 mA) were delivered at fixed times in the presence of a warning signal that remained on until a response was made. A minimum of 30 sec separated trials, but each intertrial response extended this time by an additional 30 sec from the time of the response. A second difference is the amount and type of positively reinforced key-peck training used. In the present experiment, a minimum of nine days of initial training was given before the avoidance schedule was introduced, with most of the training being on a VI 1-min schedule. Before introducing shock, Schwartz and Coulter gave only three sessions of initial training, in each of which 50 reinforcements were provided on a continuous reinforcement schedule. Finally, the type of warning signal employed in the two experiments may have contributed to the diverse results. In the present experiment, the warning signal consisted of red houselights and tone presentation. A response in this condition resulted in presentation of a white houselight-no tone condition that had been previously associated with positive reinforcement. The key was illuminated with white light at all times. In the experiment by Schwartz and Coulter, the warning signal was the illumination of the key with a green light, the stimulus condition previously associated with food reinforcement. A response in the presence of this condition resulted in removal of the green light. The choice of this particular warning signal could have reduced the probability of continued key pecking, as compared to the signal employed in the present experiment, for two reasons: (a) responses on the key during a trial were punished by removal of conditions previously associated with positive reinforcement in the case of Schwartz and Coulter; the opposite was true in the present experiment, and (b) after some period of training under Schwartz and Coulter's procedure, when the keylight had been associated with electric shock, there might have been a reduced likelihood of the bird approaching this stimulus because of its aversive nature. Evidence for this possibility was provided by Biederman, D'Amato, and Keller (1964), who found more rapid acquisition of discriminated lever-press avoidance responding in rats when the discriminative stimulus was a light on the wall opposite the manipulandum than when the discriminative stimulus and the manipulandum were on the same wall. Moore (1973) suggested that when the discriminative stimuli in avoidance procedures are localized, Pavlovian conditioning of withdrawal from these stimuli may interact with the designated avoidance response to determine the outcome.

Bolles (1970) argued that in order for a response to be rapidly acquired as an avoidance response, it must be a species-specific defense reaction (SSDR). The pigeon's key peck has generally been assumed to be a predominantly appetitive response, and thus falls outside of the class of SSDRs for the pigeon. Thus, according to Bolles' notion, such a response should be very difficult to train as an avoidance response, and for such a response to be learned, (a) one of the animal's SSDRs must be topographically compatible with the required avoidance response, and (b) shock must elicit enough reflexive avoidance responses so that the subject can either avoid some shocks or minimize their duration. Bolles' theory also attaches minimal importance to the operant level of the response at the beginning of avoidance training. In fact, Bolles' characterization of the laboratory animal in a shock-avoidance situation is that it reverts to those defensive behaviors of the wild animal and that "exploration and grooming drop out; so does all of its previously acquired appetitive behavior —bar pressing, etc." (Bolles, 1970, p. 33). It might be argued that the pecking that occurred after shock was introduced in the present experiment was not appetitive behavior, but rather was part of the pigeon's aggressive repertoire. While this is possible, other components of the pigeon's aggressive behavior such as cooing, wing raising and wing slapping (Harwood and Vowles, 1966; Lumia, 1972; McFarland and Baher, 1968) were not observed.

Ferrari *et al.* (1973, p. 216), when discussing their success in hand-shaping a key-peck avoidance response, pointed out that "the shaping of key-pecking behavior under aversive control was a painstaking procedure, requiring several hours of continuous watching and manipulating". Yet in the present experiment, the response was rapidly acquired by all eight subjects as an avoidance response. Bird 978, as shown in Figure 1, responded in the presence of the warning signal before shock on the third trial and was avoiding shock on over 75% of the signal-onset trials after fewer than 30 presentations of the signal. Ferrari *et al.* used naive birds and with these subjects a mean of over 2 hr of hand-shaping was required before the first key peck was observed. Since any especially reinforcing properties of the particular situation (such as safety-signal onset or warning-signal offset) would not come into play until after the first avoidance response was made, it is clear that the history of key-peck training had a large effect upon the likelihood of a key peck occurring in these situations.

Just as the key-peck response does not lend itself to characterization as an SSDR, neither are the criteria met that Bolles suggests are necessary for the establishment of a non-SSDR as an avoidance response. Neither freezing nor thrashing about the chamber, which are the normally observed reactions to shock shown by birds, are compatible with key pecking. In addition, the shock does not elicit reflexive avoidance responses in this situation. In fact, Smith *et al.* (1972) pointed out that the neck flexion that is elicited when birds are shocked by the method employed in the present experiment appears to be topographically incompatible with the neck extension required for key pecking.

It is not suggested here that any arbitrarily specified response may be trained as an avoidance response as easily as any other arbitrary response. Indeed, it is possible that there are some responses that may not be trained at all as avoidance responses. The present study does suggest, however, as do those of Giulian and Schmaltz (1973), Kulkarni and Job (1970), Riess (1970), and Ferrari *et al.* (1973) that variables such as ongoing level of responding and the specific stimulus conditions in the training situation are important determinants of the ease with which a given response may be trained as an avoidance response.

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