SIGNALLED AND UNSIGNALLED *FREE-OPERANT AVOIDANCE IN THE PIGEON*¹

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Pigeons were trained to depress a lever to avoid electric shock under free-operant avoidance schedules without a warning signal, or with a warning signal that could be terminated only by a response. Most birds in the signalled avoidance procedure terminated more than 50% of the warning signals before shock. In the unsignalled avoidance procedure, several birds formed a temporal discrimination and received relatively few shocks; other birds responded only in post-shock bursts, and received many more shocks.

The pigeon has been the subject of considerable behavioral research, yet little is known about its ability to avoid noxious stimuli. Hoffman and Fleshler (1959) reported great difficulty in training pigeons to escape or avoid electric shock by pecking a key, but they had some success using head lifting as the response. In a discrete-trials avoidance procedure with an auditory discriminative stimulus a single bird reached approximately 80% avoidances after 3500 trials distributed over 11 sessions. Rachline and Hine-line (1967) shaped key pecking in five of seven pigeons by using a brief timeout from a 2-sec train of shocks of linearly increasing intensity, after which shock intensity again increased from zero. In a recent modification of this procedure (Hineline and Rachlin, 1969), each peck on an illuminated key produced a 5-sec blackout, followed by 575 sec of shock-free time in the presence of the houselight and a dark key. Upon illumination of the key, 2-sec trains of very intense shock began. Three pigeons given this procedure learned to escape with very short latencies. Finally, the latter procedure was modified to resemble a standard discriminated avoidance procedure. After the key was re-illuminated, the occur-

rence 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, producing a blackout and the next cycle. One bird achieved 90% avoidances, another 30 to 70%, and a third reverted to escape responding after making some avoidance responses early in training.

Macphail (1968) employed discrete-trials avoidance procedures to train running in a shuttlebox. Within 120 trials, three of four birds trained on a one-way task reached a criterion of 90% avoidances over a 40-trial block. When two of these birds received extinction, *i.e.*, the shock could no longer occur, they met a criterion of 90% failures to avoid over a 40-trial block in 80 and 200 trials. The three pigeons that had learned one-way avoidance also were run on a two-way procedure, and reached a 90% avoidance criterion in 80 to 220 trials.

Graf and Bitterman (1963) employed general activity as the response in several free-operant avoidance procedures. Four birds were given brief sessions of unsignalled avoidance with response-shock (RS) and shock-shock (SS) intervals of 20 sec, *i.e.*, in the absence of avoidance responses successive shocks were 20 sec apart, and each avoidance response postponed the occurrence of shock for 20 sec (Sidman, 1953). Three of the pigeons received shocks at a high rate over eight sessions, while the fourth received relatively few shocks. Beginning with the ninth session, a warning signal was presented 5 sec before each scheduled

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shock. The signal was terminated by the avoidance response or by the first shock (Sidman, 1955). One bird continued to receive shocks at a high rate under this procedure, but the others tended to make avoidance responses in the presence of the warning signal and received shocks infrequently.

In the present experiment, pigeons were trained to depress a lever to avoid shock under signalled and unsignalled free-operant avoidance procedures. This response was selected because it was likely to occur in the presence of shock.

METHOD

Subjects

Seventeen adult male White Carneaux pigeons were housed individually with free access to food and water. All birds had prior histories of pecking a key under schedules of positive reinforcement, and birds T-2 and T-3 also had been trained to press a lever for positive reinforcement. None of the birds had received electric shock before this experiment. Two birds (AV-1 and AV-7) in the unsignalled avoidance group died during the experiment. Bird AV-13 was dropped from the experiment because of an erratic, low rate of responding that persisted through the third session.

Apparatus

The experimental space was an 11.5 by 11.5 by 11.5 in. (30 by 30 by 30 cm) sound-attenuating chamber with two unpainted aluminum walls and two white wooden walls. A 5.75 by 7.75 in. (15 by 20 cm) one-way mirror was centered in one wall. The ceiling consisted of a piece of translucent white Plexiglas above which were mounted two 7.5-w white lights, a 7.5-w red light, a 40-w red light, and a Utah SP25A loudspeaker. Through a hole in one aluminum wall extended a Bakelite bar to which was attached an 8 by 1.2 by 0.2 in. (21 by 3 by 0.5 cm) Bakelite lever. The lever was 0.75 in. (2 cm) from the wall and 1.2 in. (3 cm) above the hardware cloth floor when held in its rest position by a spring. A response was defined as a downward force on the lever sufficient to activate a microswitch. The switch could be activated by placing a 140-g mass on the lever.

Shock consisted of the output of a 60 Hz, 110-v ac source through a variable transformer and a 10 K ohm resistor in series with the bird.

The shock electrodes were silver chains snapped to a cable connected to the shock source via a swivel in the center of the ceiling.

Ventilation and masking noise were provided by an exhaust fan. Scheduling and recording equipment were located in an adjacent room.

Procedure

Before the experiment, feathers were removed from an area approximately 1.2 by 1.2 in. (3 by 3 cm) on the lower surface at the base of the birds' wings. Electrode paste (EKG Sol) was applied to these surfaces before each session to provide good electrical contact. The silver-chain electrodes were looped once around each wing, making contact with the exposed skin surface, and were attached to the shock cable. This method of delivering shock to pigeons was developed by Hoffman and Fleshler (1959).

One group of nine birds received a signalled free-operant avoidance procedure (Keehn, 1959; Ulrich, Holz, and Azrin, 1964). In the presence of a white houselight, each response on the lever postponed shock for 20 sec ($RS = 20$). If 10 sec elapsed without a response, a warning signal consisting of the onset of an 80-db SPL 2050 Hz tone and a change in the houselight illumination from white to red was presented. The signal could be terminated only by a response. If no response occurred within 10 sec after onset of the warning stimulus, 250-msec shocks were presented at 10-sec intervals ($SS = 10$) until the first response reinstated the RS interval. Avoidance responses that occurred in the absence of the warning signal produced a brief (100-msec) darkening of the chamber, providing added feedback. Avoidance sessions, which were 1-hr long in all cases, occurred on alternate days for AV-11, AV-12, and AV-13 and every third day for AV-4, AV-6R, AV-5, AV-6, AV-9, and AV-10. In all cases the shock intensity for the first session was 20 v ac measured across the output of the variable transformer and was increased 5 v per session until a maximum of 50 v was reached in Session 7. There was no attempt to alter the output voltage in order to compensate for changes in the birds' resistance. AV-6 received 100 v in Session 3 because of a procedural error.

A second group of birds received an unsignalled free-operant procedure (Sidman,

1953). The response-shock interval was 20 sec and the shock-shock interval was 10 sec. The chamber darkened briefly after each response, providing feedback. Shock intensity increased across sessions as in the signalled procedure. One-hour sessions occurred every third day for birds AV-1, AV-2, AV-3, AV-7, and AV-8 and on alternate days for T-1, T-2, and T-3.

With the aforementioned exceptions, all birds in both procedures received at least 16 sessions. Six of the birds in the signalled avoidance procedure received 20 to 26 sessions, and two birds in the unsignalled avoidance pro-

cedure received 27 sessions. The procedure was terminated for a bird when no marked changes in behavior had occurred over several sessions. In no case was the avoidance response shaped.

RESULTS

Signalled Avoidance

Figure 1 presents response and shock rates for individual pigeons across sessions. Birds emitted 163 to 779 responses, with a median of 347, during the first session. Characteristically,

Fig. 1. Responses in 100s (circles) and shocks in 10s (squares) over sessions for individual birds in the signalled avoidance condition. The data were lost in Session 4 for Bird AV-6R.

response rates increased across the first five to eight sessions and then decreased gradually.

It was possible for a bird to receive a maximum of 350 shocks in a 1-hr session. During the first session, however, birds received 142 to 232 shocks, with a median of 177. Generally, shock rate declined for five to eight sessions and then remained fairly stable. During the final session, the number of shocks received ranged from 33 to 120, with a median of 66. There was no consistent relation between the daily response and shock rates for individual birds; rank-order correlations (ρ) on these measures across sessions ranged from +0.62 for Bird AV-6R to -0.59 for Bird AV-12.

One measure of avoidance responding is percentage avoidance, *i.e.*, the percentage of warning signals terminated before delivery of shock (*e.g.*, Macphail, 1968; Rachlin and Hine-line, 1969). During the first few sessions, the percentage avoidance was low as the birds made most of their responses in bursts after shocks. By Session 5 or 6, however, most birds had formed a discrimination, and the percentage avoidance was at least 50%. For all birds except AV-5 responses occurred in bursts even when no shock was received. Often such bursts were due to walking along the length of the lever. During the final session the percentage

avoidances were 26, 43, 56, 61, 74, 78 and 85% for individual birds.

Figure 2 presents interresponse time (IRT) distributions for Sessions 1, 5, 10, and 16 for Birds AV-6 and AV-4. The distribution of responses for Bird AV-6 during the first session is typical of all birds. Each shock produced a burst of responses, and very few responses fell anywhere except in the first and postshock class intervals. The distribution of IRTs for Session 5 indicates that a discrimination had formed. Virtually no responses fell into class intervals 3 to 5, yet 133 responses occurred in the presence of the warning signal. The modal number of responses during the signal occurred in class interval eight, *i.e.*, 4 to 6 sec after signal onset. By Session 10, the mode had shifted to class interval seven, where it remained. The IRT distributions for Birds AV-5, AV-6R, AV-9, AV-11, and AV-12 were similar to that of AV-6, though differing somewhat in the shape of the distribution of avoidance responses during the warning signal.

The IRT distributions for Bird AV-4 across sessions revealed an increase followed by a decrease in both the over-all response rate and the percentage avoidance (see Fig. 1). The IRT distribution for Bird AV-4 was very similar to that of AV-6 in Sessions 1 and 5, but by Ses-

Fig. 2. Interresponse time distributions for Birds AV-4 and AV-6 in Sessions 1, 5, 10, and 16. Open bars represent responses before occurrence of the warning signal, filled bars, responses during the warning signal, and cross-hatched bars, post-shock responses. The bars are truncated at 200 responses, but the number of responses is presented above each truncated bar.

Fig. 3. Cumulative records of the performance of Birds AV-4 and AV-6 during Session 15. Downward deflections of the response pen represent shocks.

sion 10 the percentage avoidances made by AV-4 was declining. This trend continued through the last session.

Figure 3 presents cumulative records of the performances of Birds AV-4 and AV-6 during Session 15, illustrating the aforementioned differences in the pattern of responding.

The initial reaction to shock consisted of rapid flapping of the wings for a few beats and scrambling around the chamber for several seconds. During this activity, the bird often stepped on the lever with one foot, or ran along the length of the lever, producing a burst of responses. In most cases the response to shock had changed by the end of the first session. Little wing flapping occurred and activity had decreased. Activity that did occur was limited to the side of the chamber that contained the lever.

Birds that received relatively few shocks typically moved a short distance away from the lever after making a response, or lifted their feet, allowing the lever to remain in their grasp yet be primed for the next response. Often, the avoidance response consisted of a sudden lunge and rapid depression of the lever after the bird had been motionless for 6 to 10 sec. Pigeons that received higher shock rates often remained on the lever after a response, and released the lever only when the next shock occurred. In no case did a pigeon

depress the lever by other than a stepping movement.

Unsignalled Avoidance

Figure 4 presents response and shock rates for individual pigeons across sessions. Birds emitted from 135 to 806 responses, with a median of 363, during the first session. As in the signalled procedure, response rates typically increased over five to 10 sessions, and then either stabilized or decreased slightly. During the final session, the birds made from 342 to 1288 responses, with a median of 798.

The birds received from 135 to 199 shocks during the initial session, with a median of 156. Subsequently, two distinct patterns of avoidance responding emerged. Five birds, including two that died before the experiment was completed, responded only after shock, receiving many shocks. A second group of three birds developed a temporal discrimination, responded late during the RS interval, and received relatively few shocks. For example, during Session 16, birds in the first group received 113, 161, and 161 shocks, whereas those in the second group received 15, 23, and 31 shocks. As in the signalled avoidance procedure there was no consistent relation between the daily response and shock rates for individual birds; rank-order correlations (ρ) on these measures across sessions ranged from +0.30 for Bird T-2 to -0.68 for Bird AV-3.

Figure 5 illustrates the IRT distributions for Birds AV-2 and AV-3 during Sessions 1, 5, 10, and 16. During the first session most of AV-2's IRTs fell in the first and last class intervals. During Session 5, responses still occurred in bursts, many of which were initiated by a response late in the response-shock interval, rather than by a post-shock response. The IRT distribution for Session 10 was similar to that of Session 5; by Session 16 the number of IRTs in the first two class intervals had declined markedly, and the sixth class interval contained more IRTs than all but the first interval. The same general pattern of responding was maintained through the final session. The IRT distributions for Birds T-1 and T-2 were similar to that of AV-2.

The IRT distribution for Bird AV-3 during Session 1 was similar to that of AV-2. During Session 5, there was a great increase in the total number of responses, with a dispropor-

Fig. 4. Responses in 100s (circles) and shocks in 10s (squares) over sessions for individual birds in the unsignalled avoidance condition. The data were lost in Session 11 for Bird AV-3 and in Session 15 for Bird AV-8.

tionately large number of these occurring in the first two class intervals. There were few IRTs in the 10 to 20-sec range. Of those IRTs that exceeded 10 sec, the percentage that was between 10 and 20 sec long increased gradually to a value of 50% in Session 8 (not shown), but declined to 20% by the final session. The IRT distributions for Birds AV-1, AV-7, AV-8,

and T-3 resembled those of AV-3, but contained even fewer IRTs in the 4- to 20-sec range. Nearly all the responses of birds AV-1, AV-7, AV-8 and T-3 occurred in long post-shock bursts.

Figure 6 presents cumulative records illustrating the different patterns of performance of Birds AV-2 and AV-3 during Session 16.

Fig. 5. Interresponse time distributions for Birds AV-2 and AV-3 in Sessions 1, 5, 10, and 16. Cross-hatched bars represent post-shock responses. The bars are truncated at 200 responses, but the number of responses is presented above each truncated bar.

The topography of the avoidance response under the unsignalled avoidance procedure was similar to that obtained under the signalled procedure.

DISCUSSION

The asymptotic behavior of the pigeons under the signalled avoidance procedure may

Fig. 6. Cumulative records of the performance of Birds AV-2 and AV-3 during Session 16. Downward deflections of the response pen represent shocks.

be compared with that of three rats studied by Ulrich *et al.* (1964), who employed similar temporal parameters. When (a) the response-warning-signal interval was 14 sec and the signal-shock interval was 6 sec, or (b) the response-warning-signal interval was 6 sec, and the signal-shock interval was 14 sec the rats made more than 70% of their avoidance responses in the presence of the warning signal. Keehn (1959) obtained a similar result for rats in a wheel-running avoidance task under a different set of temporal parameters. Since the pigeons in the present experiment tended to respond in long bursts, the temporal distribution of their avoidance responses is similar to that of the rats only if IRTs shorter than 2 sec are ignored. Two of the rats terminated more than 90% of the warning signals before a shock occurred, while the pigeons attained a median of 67.5% avoidances on the last day of training. Finally, the "warm-up" phenomenon (Hoffman, Fleshler, and Chorney, 1961) was virtually absent in the rats of Ulrich *et al.* but did occur for two pigeons (AV-6 and AV-6R).

When rats learn to press a lever and avoid unsignalled shocks they pass through a stage of acquisition in which they respond immediately after each shock, but make very few additional avoidance responses. Ellen and Wilson (1964) noted that some rats persist in

this behavior for prolonged periods of time while others acquire more effective avoidance behavior. Birds AV-1, AV-7, AV-8, and T-3 of the present experiment persisted in the former pattern, while the others began to make late responses. Several birds were observed standing on the lever for the duration of the RS interval, another behavior often seen in rats (Feldman and Bremner, 1963). The "warm-up" phenomenon characteristic of rats in unsignalled avoidance procedures also characterized all three birds that had low shock rates.

The present results along with those of Graf and Bitterman (1963) and Macphail (1968) suggest that pigeons can be trained to avoid electric shock under standard negative-reinforcement procedures when the to-be-trained response has a high initial probability of occurrence in the presence of shock.

REFERENCES

- Ellen, P. and Wilson, A. S. Two patterns of avoidance responding. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 97-99.
- Feldman, R. S. and Bremner, F. J. A method for rapid conditioning of stable avoidance bar pressing behavior. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 393-394.
- Graf, V. and Bitterman, M. E. General activity as instrumental: application to avoidance training. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 301-306.
- Hineline, P. N. and Rachlin, H. Escape and avoidance of shock by pigeons pecking a key. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 533-538.
- Hoffman, H. S. and Fleshler, M. Aversive control with the pigeon. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 213-218.
- Hoffman, H. S., Fleshler, M., and Chorney, H. Discriminated bar press avoidance. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 309-316.
- Keehn, J. D. The effect of a warning signal on unrestricted avoidance behavior. *British Journal of Psychology*, 1959, 50, 125-135.
- Macphail, E. M. Avoidance responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 629-632.
- Rachlin, H. C. and Hineline, P. N. Training and maintenance of key pecking in the pigeon by negative reinforcement. *Science*, 1967, 157, 954-955.
- Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, 118, 157-158.
- Sidman, M. Some properties of the warning stimulus in avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1955, 48, 444-450.
- Ulrich, R. E., Holz, W. C., and Azrin, N. H. Stimulus control of avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 129-133.

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