ESCAPE AND AVOIDANCE OF SHOCK BY PIGEONS PECKING A KEY

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Pigeons had been trained to peck a key when each peck removed a slowly increasing series of electric shocks. Without loss of the established key-pecking response, the birds were gradually weaned from this procedure to one where intense shocks were presented suddenly, duplicating features that had proved ineffective for initial shaping of the response. Finally, a procedure was introduced in which key pecks could avoid shock. Avoidance responding was maintained in two of three pigeons.

Much of the work reported in this Journal has shown that when on schedules of positive reinforcement, pigeons behave much like other animals. A pigeon's key peck is a convenient analog to a rat or monkey's lever press. Pigeons have also been frequently used in studies where electric shocks are used to punish appetitively maintained responses (*e.g.*, Azrin, 1960; Azrin and Holz, 1961; Holz, Azrin, and Ulrich, 1963). The punished behavior of pigeons appears similar to comparable behavior of rats and monkeys (Appel and Peterson, 1965; Hake, Azrin, and Oxford, 1967). But pigeons have been neither convenient nor typical subjects for escape or avoidance schedules of shock. Undocumented personal communications report failures of pigeons to avoid; a brief reference by Dinsmoor (1967) suggests that this has been a general finding. Even without these one could predict, from the conspicuous scarcity of systematic studies of pigeons on these schedules, that standard escape and avoidance procedures are ineffective when applied to pigeons. We have discovered only four published reports of escape or avoidance in pigeons: Azrin (1959*b*) shaped key pecking in one pigeon, using manual control of shock intensity. Hoffman and Fleshler (1959) failed to get key pecking, but did shape and maintain head-

lifting responses with escape contingencies and, in one bird, maintained head-lifting with avoidance contingencies. Macphail (1968) trained pigeons to escape and avoid shock with an ambulatory response in a shuttle box. The only study that maintained key pecking extensively was one by Azrin, Hake, Holz, and Hutchinson (1965), who arranged for a peck on one key to remove a punishment contingency from positively reinforced responding on a second key, thus, in a sense, avoiding shocks. The first three of these experiments suggest possible sources for the difficulty in conditioning pigeons' responses with shock removal. The study by Azrin, and that by Hoffman and Fleshler, suggest that the pigeon's sensitivity to shock must fluctuate, for in both of these studies shock intensity was adjusted frequently. Another likely source of difficulty is shock-produced behavior incompatible with the response to be shaped.

The present authors have reported a procedure designed to minimize these two problems; stable key pecking was shaped and maintained by response-contingent shock removal when the shock was a slowly increasing series of pulses (Rachlin and Himeline, 1967). This basic procedure supported responding on both fixed-interval and fixed-ratio schedules of shock removal (Himeline and Rachlin, 1969). In the present experiments, responding was maintained while the gradually increasing shock was transformed into sudden and intense shock. The pigeons were subsequently trained to avoid shock by pecking the key during periods when the shock was not present.

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METHOD

Subjects

Three adult male White Carneaux pigeons, whose early performance on aversive schedules has been reported previously (Rachlin and Hineline, 1967), were used. Birds 270 and 319 had been trained to peck for food; this pecking had subsequently been extinguished. Bird 499 was experimentally naive at the beginning of the experiment. In all birds, gold wires were implanted under the pubis bones (Azrin, 1959a), and the birds were given free access to food and water in their home cages.

Apparatus

The experimental chamber of standard dimensions (Ferster and Skinner, 1957) was made of wire mesh coated with an insulating spray. The shock was 110 v ac transformed by a 0 to 110 v variable transformer, then stepped up by a 400-v transformer, and run through a 25 K or larger resistor, through relay contacts which closed to produce a 35-msec pulse every second, and through a Gerbrands mercury swivel mounted on the ceiling of the chamber. The variable transformer was driven by a motor and gear changer (or by a stepping device, in some of the later work) with a clutch arrangement. This apparatus provided for trains of shock pulses, with intensity linearly increasing in time, and for sudden reset of the intensity to zero. In all of the following experiments, the maximum shock was 8.5 ma. If the shock reached 8.5 ma, it remained at that value until reset. The experimental chamber was contained in a sound-resistant chest; white noise was supplied throughout. There was a houselight on the roof of the experimental chamber, and a transilluminated key was mounted on the wall, 10 in. above the floor.

Preliminary Procedures and Results

As described previously, for initial conditioning, trains of 2-per-sec pulses were presented, shock intensity increasing very slightly with each pulse, in the presence of a dim and diffuse houselight and the transilluminated response key. Successive approximations to key pecking were reinforced by resetting the shock suddenly to zero for 5 sec during which all lights were off. When the lights came back on, the shock again increased linearly from zero intensity. Key pecks automatically pro-

duced the blackout and shock reset. It was found helpful to mount a transparent hemispherical extension on the response key during training; the extension could be removed after initial training. These procedures produced reliable key pecking in five of seven birds, but several hours of shaping were required for four of the five. A procedure for automatically shaping key pecking with negative reinforcement similar to Brown and Jenkins (1968) "autoshaping" procedure was also somewhat successful (Rachlin, 1969).

Once established, key pecking was easily manipulated with a wide range of rates of shock increase (0.0374 ma/min to 37.4 ma/min). At the highest and lowest rates of increase, pecking was erratic; within the extremes, responding was systematically related to the controlling conditions; when shock intensity increased rapidly, the pigeons pecked at higher intensities than when shock increased slowly.

After these experiments the pigeons were exposed to several procedural variations intended to produce avoidance responding. These variations entailed removal of shock for short periods during shock increase, and replacing the shock by a signal. Pecking during the signal would have avoided the more intense shock to come. These variations were unsuccessful. The pigeons generally did not peck during the short shock-free periods even though these periods were inserted at times during the course of shock increase when the pigeons had previously pecked frequently. The pigeons were also exposed to fixed-interval and fixed-ratio escape conditioning reported elsewhere (Hineline and Rachlin, 1969).

Procedure A. Escape from Sudden Shock

The basic escape procedure was modified as diagrammed in Fig. 1. In the first session, the 5-sec blackout was followed by an additional 25 sec of shock-free time; the shock-intensity programmer increased at its usual rate (indicated by the dashed line in the figure), but shocks were not delivered. During this shock-free time, only the houselight was illuminated and key pecks were ineffective. At the end of the 25 sec, the key was illuminated and shocks were delivered as if there had been no additional shock-free time. Pecks from then on were effective. On the following day, the shock-free period was 50 sec; the shock intensity at

Fig. 1. Diagram of procedure for developing escape from shock with sudden shock onset. The heavy line indicates shock intensity; time since blackout is indicated on the abscissa. As indicated by the arrow, the time from blackout to shock onset was varied (from day to day). The diagonal line describes the intensity of shock at its onset as a function of time until that onset; the diagonal also describes the growth in intensity of the shocks after onset of the train of shocks.

onset was 0.62 ma. For each successive session, this shock-free period was increased by 25 sec with a corresponding increase in the intensity of shock at its onset (in Fig. 1, the duration of shock-free time is indicated by the variable *X*) until it reached a value of 575 sec. On this final session, the intensity of shock at its onset was 7.15 ma. Birds 270, 319, and 499 were run on this procedure.

Results of Procedure A

All three birds responded throughout this procedure. Figure 2 shows the median latency of response, measured from end of blackout, for each bird as a function of time from end of blackout to onset of shock. The points corresponding to zero on the abscissa represent median latencies for these subjects in a previous experiment, where shock increase was gradual from its beginning. As the time to shock onset was increased from zero, the median latency decreased for two of the three birds. The third bird, 270, began with an extremely small median latency and had little room for decrease. The median latencies of the two continued on a generally decreasing trend until they approached the time of shock onset. Thereafter, as the intensity of shock at onset increased from session to session, the median latencies followed closely along the 45-degree line that corresponds to responding

Fig. 2. Median time until response as a function of the interval between blackout and shock onset for Pigeons 270, 319, and 499. The diagonal line describes the locus where data points would lie if the birds always responded immediately at shock onset. Each data point is based on a single session.

immediately upon the onset of shock. The dispersion of response latencies (not shown) tended at first to increase as the median latency decreased. But this dispersion decreased markedly as soon as the median latency approached the time of shock onset.

Procedure B. Avoidance

The sudden shock procedure was changed to resemble standard discriminated avoidance

Fig. 3. Diagram of avoidance procedure. Time since blackout (or since the beginning of the session, for the first trial) is represented on the abscissa. The heavy line describes shock intensity. As indicated, pecks during the 25-sec "avoidance period" produced a blackout and prevented the onset of shock.

procedures (Hoffman, 1966). The 5-sec blackout was always followed by a 475-sec shock-free ("intertrial") interval during which key pecks were ineffective and only the house-light was illuminated (see Fig. 3). At 475 sec, the keylight was illuminated ("warning stimulus"), and the response key was made effective, but no shocks were delivered. If no response had occurred by the five-hundredth second, shock was introduced, beginning at an intensity of 6.20 ma and increasing at the rate of 0.745 ma/min until a peck occurred. Thus, a peck between the four hundred seventy-fifth and five-hundredth sec turned off the "warning stimulus" and prevented the occurrence of shock; a peck after the five-hundredth second resulted in escape from shock.

Results of Procedure B

This procedure produced appreciable avoidance responding in two of the three birds. Figure 4 shows per cent avoidance as a function of sessions. "Per cent avoidance" is equal to the number of avoidance responses divided by the total number of trials, expressed as a per cent. Bird 270 quickly came to avoid on approximately 90% of all trials. Bird 499 avoided between 30% and 70%, with considerable day-to-day fluctuation, and Bird 319 emitted some avoidance responses during the first 18 sessions of the procedure, but eventually reverted to escape responding. It may be significant

that this bird had a considerably shorter conditioning history than the other two. It had been omitted from some of the procedures mentioned previously.

DISCUSSION

With the procedure used for initial shaping and maintenance of key pecking, it was not clear whether a response was reinforced by the removal of shock that was scheduled at the time of the response, or by the prevention of more intense shocks to come. In one case we would say that the response was maintained by escape contingencies; in the other, that the response was maintained by avoidance contingencies. Mowrer (1940) used a similar procedure with rats and found that they came to respond at low shock intensities—in the words of Kimble (1961, p. 69): "as soon as they could feel the shock." Kimble concluded that the rats' responding was maintained as avoidance rather than as escape. The pigeons in the present experiments did not confine their responses to low shock intensities, but avoidance contingencies could have been operative here, too.

Whether the birds were avoiding or escaping on Procedure A, performance on this procedure was closely correlated with that on Procedure B, the *bona fide* discriminated avoidance procedure. Bird 270, which avoided best on Procedure B, had responded most at low intensities on Procedure A and on earlier procedures. Bird 319, which avoided least well on Procedure B, had responded only at high intensities on Procedure A and on earlier procedures. This correlation between performances on different procedures may be based directly on differing sensitivities to shock that perhaps stem from differing electrode implants. On the other hand, the correlation may mean that some birds (270 in particular) were indeed avoiding on all the procedures. If sensitivity to shock, as measured by the intensities at which a given pigeon responded on Procedure A, determined whether a given pigeon would avoid on Procedure B, it should follow that higher intensities of shock onset in Procedure B would have increased the avoidance responding of those pigeons that avoided infrequently. Unfortunately this notion has not yet been tested.

Fig. 4. Per cent avoidance as a function of sessions of exposure to the avoidance procedure, for Pigeons 270, 319, and 499. Per cent avoidance was computed by dividing the number of avoidance responses in a session by the total number of trials in that session. This latter was also equal to the sum of avoidance and escape responses.

Through this and previous work there have been hints that exposure to shock reduces the subsequent effective intensity of shock; with continued exposure, strong shocks come to resemble weaker ones in their effects on behavior. Evidence for such adaptation or habituation to shock is supplied by the results of Procedure A, where sudden onset of shock replaced the gradual increase from zero. Responding shifted systematically to lower shock intensities when the shock no longer increased gradually from zero, suggesting that the shock was made effectively more intense by its sudden onset or by the interpolated intervals of shock-free time. Elsewhere, pigeons' adaptation to electric shock has been observed when mild shock is used to punish appetitively maintained key pecking (Azrin, 1959c; Rachlin, 1966). The punishment produces most suppression at the beginnings of sessions, except when a timeout is inserted in mid-session, producing renewed potency of the punishing shock (Azrin, 1960). The interpolation of shock-free intervals in some of our preliminary procedures was accompanied by shifts of responding to lower intensities. Also, there were hints of adaptation during an initial, abortive attempt to produce escape responding in pigeons, where we used continuous shock instead of pulsing shock. The shock was somewhat effective at the beginnings of sessions, but the birds appeared quickly to become insensitive as sessions continued. Whether such changes in effectiveness of shock with exposure are based on sensory adaptation or on some more obscure process, remains an open question. Certainly they are worthy of specific study instead of being observed only as by-products or secondary effects in studies on other topics.

The present experiments have introduced procedures that produce, in the pigeon, negatively reinforced behavior somewhat comparable to that observed in other species. Some features of these experiments, such as the gradual shock increase during shaping of a new response, and transitional procedures for changing from gradual shock increase to sudden shock onset, may prove necessary for negative reinforcement with pigeons and other species that are refractory to standard negative reinforcement procedures. In addition, it is likely that some of these features could make negative reinforcement more effective

for animals that respond relatively well on the present standard procedures.

REFERENCES

- Appel, J. B. Punishment and shock intensity. *Science*, 1963, 141, 528-529.
- Appel, J. B. and Peterson, N. J. Punishment: effects of shock intensity on response suppression. *Psychological Reports*, 1965, 16, 721-730.
- Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 161-163. (a)
- Azrin, N. H. Some notes on punishment and avoidance. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 260. (b)
- Azrin, N. H. Punishment and recovery during fixed-ratio performance. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 301-305. (c)
- Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 123-142.
- Azrin, N. H. and Holz, W. C. Punishment during fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, 1961, 4, 343-347.
- Azrin, N. H., Hake, D. F., Holz, W. C., and Hutchinson, R. R. Motivational aspects of escape from punishment. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 31-44.
- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Dinsmoor, J. Escape from shock as a conditioning technique. In Marshall R. Jones (Ed.), *Miami Symposium on the Prediction of Behavior*, 1967. *Aversive Stimulation*. Coral Gables, Florida: University of Miami Press.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Hake, D. F., Azrin, N. H., and Oxford, R. The effects of punishment intensity on squirrel monkeys. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 95-107.
- Hineline, P. N. and Rachlin, H. C. Notes on fixed-ratio and fixed-interval escape responding in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 129-133.
- Hoffman, H. S. Discriminated avoidance. In W. K. Honig (Ed.), *Operant conditioning: areas of research and application*. New York: Appleton-Century-Crofts, 1966, Pp. 499-530.
- Hoffman, H. S. and Fleshler, M. Aversive control with the pigeon. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 213-218.
- Holz, W. C., Azrin, N. H., and Ulrich, R. E. Punishment of temporally spaced responding. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 115-122.
- Kimble, G. A. *Hilgard and Marquis' Conditioning and Learning*. New York: Appleton-Century-Crofts, 1961. Pp. 68-91.
- Macphail, E. M. Avoidance responding in pigeons. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 625-632.

Rachlin, H. C. Recovery of responses during mild punishment. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 251-263.

Rachlin, H. C. and Himeline, P. N. Training and maintenance of key pecking in the pigeon by nega-

tive reinforcement, *Science*, 1967, 157, 954-955.

Rachlin, H. C. Autoshaping of key pecking in pigeons with negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 521-531.

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