DEVELOPMENT AND MAINTENANCE OF ATTACK IN PIGEONS DURING VARIABLE-INTERVAL REINFORCEMENT OF KEY PECKING[1]

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Key-peck responses of two pigeons were maintained on variable-interval schedules of food reinforcement in the presence of a stuffed pigeon to study the characteristics of attack induced by that schedule. The mean interval of the schedule was increased from 15 sec to 600 sec in eight steps before an intermediate interval was reintroduced. The principal characteristics of attack were: (1) substantial attack first occurred on a variable-interval schedule of 90 sec in one pigeon and at 180 sec in the other, (2) the highest attack rates occurred on variable-interval schedules of 300 sec and 600 sec, (3) attack rate generally increased to a maximum and then decreased to a lower level across sessions at each schedule, (4) attacks developed a postreinforcement locus across the initial sessions on all schedules and, except on variable-interval schedules of 300 and 600 sec, occurred primarily in the postreinforcement period during extended training, (5) attack rates and key-peck rates were not recovered when the intermediate-length schedules were reintroduced, and (6) attack rate and key-peck rates were negatively correlated. Except for the fact that the maximum attack rates occurred at interfood intervals of 300 and 600 sec, and that attack and key-peck rates were negatively correlated, these findings have counterparts in experiments with other reinforcement schedules.

Among the simple ratio and interval schedules of positive reinforcement, only variable-interval (VI) schedules have not been studied as conditions that induce attack in pigeons. Attack occurs on both fixed- and variable-ratio (FR and VR) schedules (Gentry, 1968; Webbe, DeWeese, and Malogodi, 1972; respectively) and on fixed-interval (FI) schedules (Cherek, Thompson, and Heistad, 1973; Richards and Rilling, 1972). The major purpose of the present experiment was to study attack in pigeons trained on VI schedules. Three characteristics of attack noted in experiments with the other reinforcement schedules were chosen for particular study.

First, rate of attack increases to a maximum and then decreases as the interfood interval is progressively lengthened in FI and FR schedules (Cherek et al., 1973; Cohen and Looney, 1973, respectively) and in fixed-time (FT) schedules in which food presentations after fixed periods of time are not dependent upon an operant response (Flory, 1969). In these experiments, the highest attack rates occurred when the interfood interval was between 60 and 180 sec. The present experiment employed an ascending series of nine average interfood intervals between VI 15-sec and VI 600-sec to establish the relationship between rate of attack and interfood intervals arranged by VI schedules.

Second, after extended training, attack rate in a given FR schedule declines to near-zero levels and subsequently increases when the ratio is lengthened, but not when it is shortened (Cherek and Pickens, 1970). The present experiment studied whether extended training and changes in the length of the average interfood interval would produce comparable changes in attack rate on VI schedules.

Finally, in most studies, attack occurs primarily in the period shortly after reinforcement (e.g., Flory, 1969; Gentry, 1968; Knutson, 1970). To establish whether most attacks follow reinforcement on VI schedules, the percentage of attacks in a period immediately after reinforcement was computed in each ses-

sion. Session-by-session plots of these percentages show whether attack develops a postreinforcement locus across sessions or occurs primarily in the postreinforcement interval from the outset of training. These plots also show whether attack maintains a postreinforcement locus throughout extended training.

METHOD

Subjects

Pigeons 2 and 8, adult male White Carneaux from the Palmetto Pigeon Plant, Sumter, South Carolina, served. Before this experiment, the pigeons had key pecked for food with no target pigeon present on a multiple VI 300-sec extinction schedule. Both pigeons were maintained at 80% of their free-feeding body weights throughout the present experiment. They were individually housed in a continuously lighted colony room.

Apparatus

The experimental chamber was an enclosed box, 30 by 35 by 33 cm, with a shielded observation window. Two translucent response keys were mounted on one wall 10.2 cm apart and 22.3 cm from the floor. A solenoid-operated food hopper contained mixed grain and could be raised to a 5.5 by 4.5-cm opening centered below the keys, 5.5 cm above the floor. A white light illuminated the opening while the hopper was raised. A taxidermically prepared White Carneaux target pigeon was mounted on a pivoted metal plate behind the wall opposite the response keys. The target pigeon was prepared in a natural standing position and approximately the upper two-thirds of its body protruded slightly through a 15 by 25-cm rectangular opening in the upper center of the wall. The tip of the target's beak was 22 cm above the floor and 27.5 cm from the opposite wall. A 5.2-cm wide semicircular aluminum band was mounted directly below the target opening and protruded in a horizontal plane 5 cm into the chamber at the center of the opening. This band prevented casual contact with the target pigeon during the experimental pigeons' normal ambulation. The metal plate on which the target was mounted was balanced above a snap-action switch, so that displacement of the target with a force greater than 55 g (0.539 N) at the switch resulted in a contact closure. A 7-W houselight, shielded to reflect light onto the ceiling, was located to the target's upper left on the wall perpendicular to the target wall. All events in the experimental chamber and all data collection were controlled by a PDP 8-I computer interfaced through a Grason-Stadler Co. SCAT system.

Procedure

The left key was transilluminated with a white light throughout experimental sessions, except during the 3-sec presentations of the grain hopper which were contingent upon a key peck and were arranged according to the prevailing VI schedule. Pecks on the target pigeon and on the unlighted right key had no scheduled consequences. The houselight remained on throughout each session. Each pigeon was trained on VI 15-, 30-, 45-, 60-, 90-, 120-, 180-, 300-, and 600-sec schedules, in that order. A redetermination period was given at the schedules at which substantial attack first occurred, VI 90-sec for Pigeon 2 and VI 180-sec for Pigeon 8. Since each session was terminated after 64 reinforcers, except for occasional sessions in which apparatus failure caused premature termination, session length varied from approximately 16 min at VI 15-sec to over 10 hr at VI 600-sec. The criterion for changing to a new VI length was a zero or near-zero attack rate for several consecutive sessions, unless it appeared that a near-zero rate would not be reached in a reasonable number of sessions.

Each VI schedule was composed of 16 minimum interreinforcement intervals in a Fleshler-Hoffman (1962) distribution. At VI 60-sec, intervals of 46, 56, 123, 22, 37, 12, 15, 80, 111, 27, 144, 27, 10, 10, 163, and 84 sec were repeated four times in each session, with an irregular starting point in the series at the beginning of each session. The other schedules were composed of appropriate fractions or multiples of these intervals. The primary data gathered in each session were key-peck rate, attack rate, and the percentage of attacks in a period following each reinforcement equivalent to the shortest interfood interval on the prevailing schedule, *e.g.,* 10 sec for VI 60-sec.

RESULTS

The top two panels of Figures 1 and 2 are session-by-session plots of rate of key pecking

and rate of attack for the pigeons at each of the VI schedules. Figure 1 shows that in the ascending series of VI schedules, Pigeon 8 attacked very little until VI 180-sec was reached, and attacked at substantial rates in the remaining schedules. Figure 2 shows that Pigeon 2 attacked at VI 15-sec but then attacked very little until VI 90-sec was reached, and that it attacked at substantial rates in all the remaining schedules except VI 180-sec. Although attack rate was variable from session to session, there was a general increase in

attack across the initial sessions on a given schedule, followed by a decrease across the remaining sessions. This increase-decrease pattern was particularly evident for Pigeon 8 at VI 180-, 300-, and 600-sec, and for Pigeon 2 at VI 90-, 120-, and 300-sec. The pattern was also suggested by the data of Pigeon 2 at VI 600-sec, but there was not a clear increase in rate in the initial sessions. Very little attack occurred when the schedule was shortened from VI 600-sec to VI 180-sec for Pigeon 8 or to VI 90-sec for Pigeon 2.
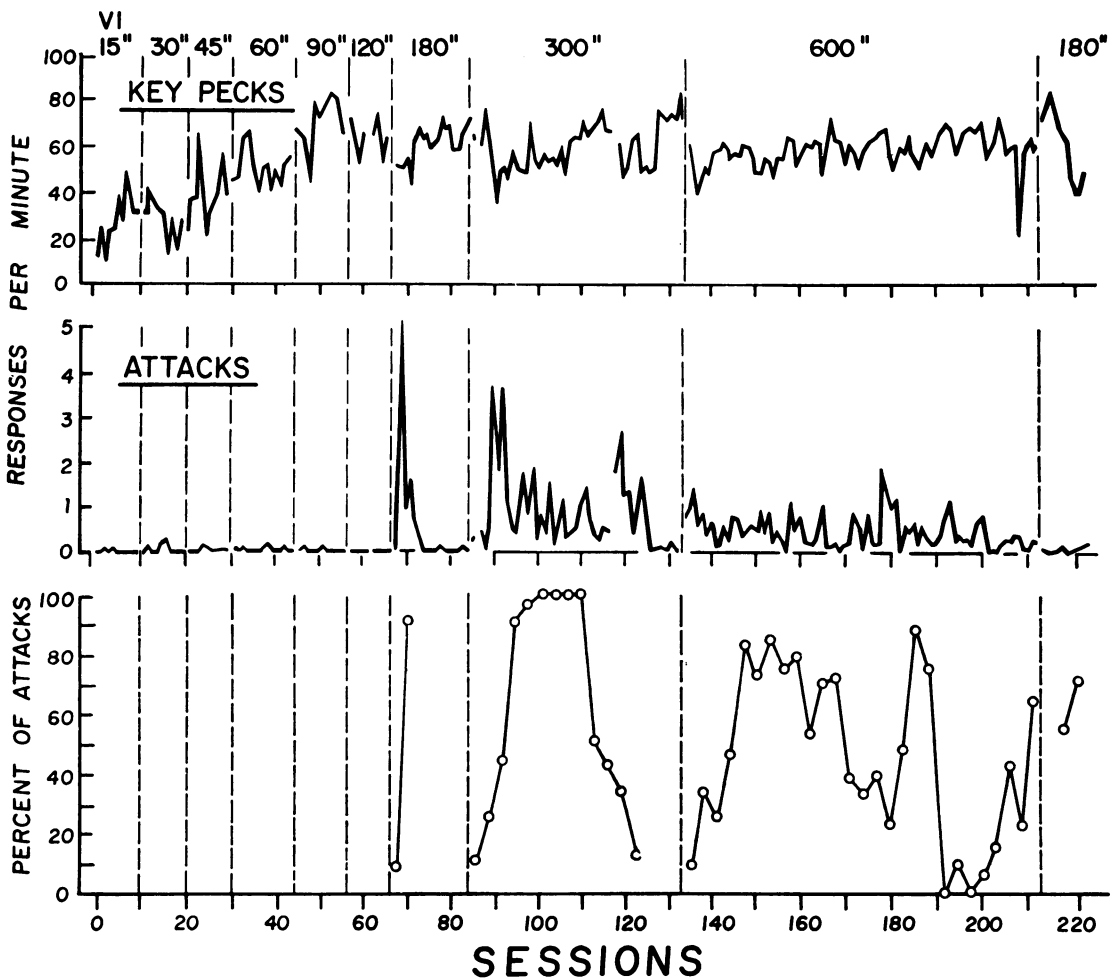

Fig. 1. The top two panels show key-peck rate and attack rate in each session of the experiment for Pigeon 8. Except at the transition from one schedule to the next, a break in a line indicates a session for which data were not available. Each point in the bottom panel is the median per cent of attacks immediately after reinforcement in a period equal to the shortest interreinforcement interval arranged by the prevailing VI schedule. Medians were computed over successive three-session blocks and whenever the total number of attacks in the median session was less than 20, the median for that block was not plotted and the adjacent data points were not joined.
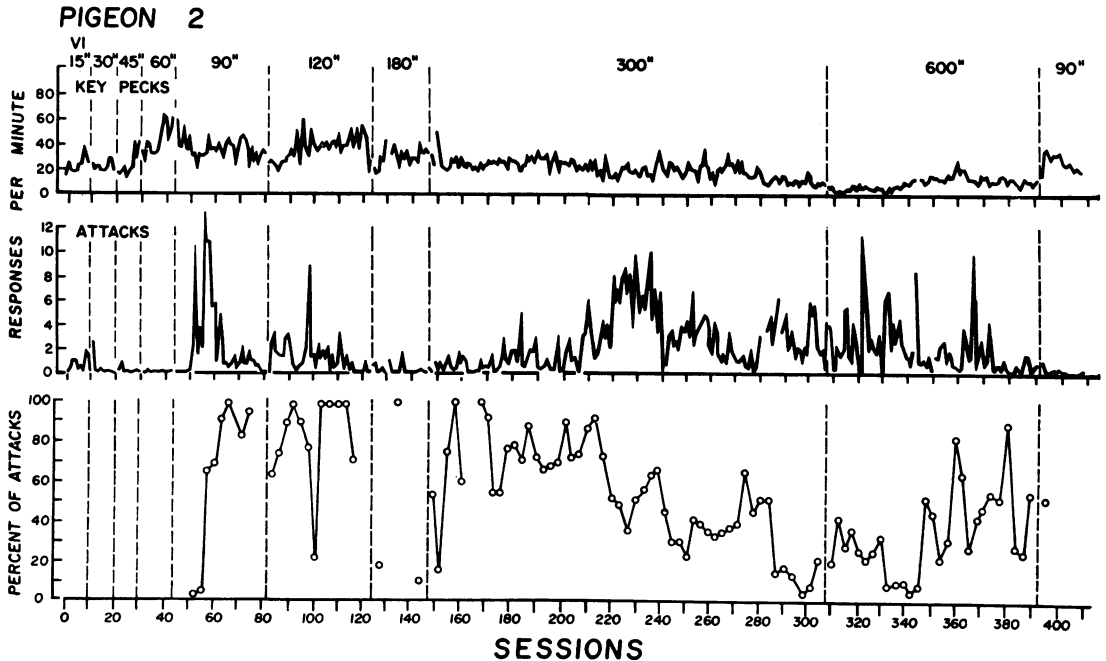
Fig. 2. Key-peck and attack data for Pigeon 2 (see Figure 1 caption for details). Note that the scale on the ordinate for the attack rate panel is twice the scale in Figure 1.

A description of the relationship between attack rate and length of VI schedule is not straightforward because averaged rates on the various schedules may be influenced by the criterion employed for changing the schedule. The criterion was designed to ensure that sessions at each schedule would continue long enough to show whether a decrease in attack rate across sessions was characteristic of VI schedules and, as applied here, this criterion permitted rather large differences among schedules in the number of sessions with very low attack rates. Acknowledging these reservations, Figure 3 shows two estimates of the relationship between average attack rate and average interfood interval on the VI schedules for each pigeon. One estimate is the median attack rate over the minimum number of sessions on each schedule (10 sessions) and the other is the median over all sessions on each schedule. Figure 3 shows that for both pigeons, the 10-session median attack rates increased across VI 180-, 300-, and 600-sec, whereas the all-session medians increased between VI 180-sec and VI 300-sec but decreased at VI 600-sec. A Mann-Whitney test showed that this decrease was statistically significant for both pigeons ($p < 0.05$, one-tailed test).

Across the six schedules between VI 15-sec and VI 180-sec, however, the functions for the two pigeons differ. Pigeon 8 attacked at near-zero rates at all schedules, whereas the function for Pigeon 2 approximated a U shape with near-zero rates in a range between VI 30- and 60-sec in the 10-session medians and between VI 30- and 90-sec in the all-session medians.

The bottom panels of Figures 1 and 2 show the per cent of attacks that fell in the post-reinforcement period on each schedule. Each data point is the median of three successive sessions and medians were plotted only when the total number of attacks in the median session was greater than 20. These figures show that on those schedules in which substantial attack occurred, attack developed into a predominantly postreinforcement behavior over several sessions. Initially, on each schedule the percentage of attacks in the postreinforcement period was relatively low, and after a variable number of sessions reached a maximum of 90 to 100%, except at VI 600-sec where the maximum was about 80%. Even the fragmentary data at VI 180-sec suggest development of a postreinforcement locus of attacks for both pigeons. With continued training at schedules shorter than VI 300-sec,
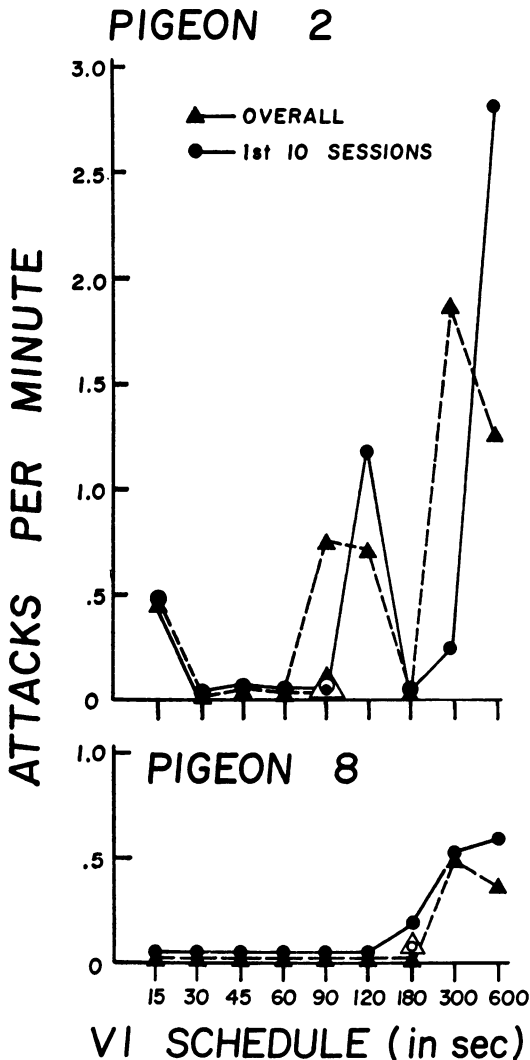
PIGEON 2

Fig. 3. Median attack rates as a function of VI schedule for each pigeon. The circles show attack rates averaged over the first 10 sessions on each schedule, while the triangles show medians over all sessions on each schedule. The open circles and triangles show attack rates during the redeterminations.

attack remained predominantly in the postreinforcement period until the schedule was changed. Attacks increasingly migrated beyond the postreinforcement period for both pigeons as training continued at VI 300-sec, whereas at VI 600-sec, only about half of the attacks fell in the postreinforcement period for Pigeon 2 in the last 40 sessions, and a cyclic decrease-increase in the per cent of postreinforcement attacks was shown by Pigeon 8.

At least at some schedules, the figures suggest an inverse relation between attack rate

and key-peck rate for both pigeons. Correlations between attack and key-peck rates were computed for each VI schedule with rates in each session on the various schedules serving as the individual observations. The correlations were uniformly negative for both pigeons at all VI schedules in which substantial attack occurred. For Pigeon 2, the correlation coefficients at VI 90-, 120-, 180-, 300-, 600-, and at the final VI 90-sec schedule were -0.05, -0.21, -0.16, -0.27, -0.18, and -0.45, respectively. Only the correlation coefficient at VI 300-sec was statistically significant ($p < 0.05$). For Pigeon 8, significant ($p < 0.05$) correlation coefficients were found at each schedule (r = -0.52, -0.61, -0.47, and -0.71 for VI 180-, 300-, 600-, and the final VI 180-sec schedule, respectively).

Frequent observations through a viewing window in the experimental chamber indicated that contact with the stuffed target in these VI schedules included strong pecks at the head area, charging, and pulling of feathers in the breast and neck regions, and was generally similar to that described by Azrin, Hutchinson, and Hake (1966).

DISCUSSION

The present experiment showed that pigeons will attack a stuffed pigeon during variable-interval reinforcement of key pecking, and identified several characteristics of attack induced by VI schedules.

These data demonstrate that on a given VI schedule, attack rate increases and then decreases across sessions, and that attack rate is not recovered when an intermediate-length VI schedule is arranged after a relatively long VI schedule has been in effect. Analogous findings have been reported with FR schedules (Cherek and Pickens, 1970). These data are consistent with the view that attack occurs when the demands of a schedule (and, usually, the interreinforcement interval) are increased, but not when they are decreased (Cherek and Pickens, 1970). However, data contradictory to the latter part of this view come from experiments in which attack rates have been recovered successfully with FT schedules (Flory, 1969), FI schedules (Cherek et al., 1973), and multiple FR FR schedules (Cohen and Looney, 1973).

The finding that attack developed into a predominantly postreinforcement behavior across the initial sessions on each VI schedule is comparable to schedule-induced attack data obtained with pigeons trained on FI schedules (Cherek and Heistad, 1971) and with monkeys trained on FR schedules (Hutchinson, Azrin, and Hunt, 1968). A recent experiment has shown a comparable shift in the temporal distribution of another schedule-induced behavior, polydipsia, within the first session of training (Schaeffer and Salzberg, 1973). These findings indicate that behaviors induced by schedules of positive reinforcement develop a postreinforcement locus as training progresses, and this argues against these behaviors being maintained by adventitious reinforcement.

The FI and FR schedules employed in most previous experiments establish a pattern of operant responding characterized by a pause after reinforcement. Because nearly all attack occurs in this postreinforcement pause (*e.g.*, Cherek *et al.*, 1973; Gentry, 1968) attacks should be virtually independent of operant behavior. However, the relatively constant rate of operant responding throughout the interreinforcement interval in VI schedules makes it more likely that attack and operant behavior will interact, and the negative correlations found between attack rate and key-peck rate in the present experiment document this interaction. At a given interfood interval (*e.g.*, 60 sec), high attack rates might be unlikely on a VI schedule relative to a FI schedule. Experiments are indicated that study attack rate as a function of fixed and variable interfood intervals, and that include response-contingent (FI, VI) and non-contingent (FT, VT) conditions. Such experiments will allow the roles of variability of the interfood interval and pattern of responses established by the schedule to be assessed.

The relationship between attack rate and average interfood interval arranged by VI schedules ranging between VI 15- and VI 600-sec is unclear from the present experiment. In general, there was little or no attack when the average interfood interval was shorter than 90 sec, and attack rates were higher at VI 300- and VI 600-sec than at schedules with shorter interfood intervals. The latter finding, in particular, is discrepant with the fact that highest attack rates occurred when the interfood interval was between 60 and 120 sec on FT schedules (Flory, 1969) and FR schedules (Cohen and Looney, 1973), and between 120 and 180 sec on FI schedules (Cherek *et al.*, 1973). This discrepancy may be related to the interaction of operant responding and attack on VI schedules, as discussed above. However, the variability in attack rates between the animals and the flexible criterion for shifting from one VI schedule to another make it impossible to determine whether an increasing-decreasing bitonic function describes the relation between average attack rate and increasing interfood interval. Such a function has been reported when pigeons were trained on FT schedules (Flory, 1969), FI schedules (Cherek *et al.*, 1973), and FR schedules (Cohen and Looney, 1973).

In summary, several characteristics of attack induced by VI schedules were found to be comparable to those found when attack is induced by other reinforcement schedules. The major exceptions were that highest attack rates occurred at longer interfood intervals in the present experiment than has been reported on FR, FI, and FT schedules, and that key-peck rate and attack rate were negatively correlated. These findings indicate that the variability of the interfood interval and the operant response pattern established by the reinforcement schedule are variables whose influence on schedule-induced attack deserve further study.

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