THE ROLE OF INTERMITTENT FOOD IN THE INDUCTION OF ATTACK IN PIGEONS

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The present experiments evaluated whether transitions in reinforcer probability are necessary to induce attack in pigeons. In Experiment I, three of six pigeons exposed to response-contingent constant-probability food schedules and a photograph of a conspecific as a target exhibited sustained postreinforcement attack on the target. The postreinforcement pattern of attack developed over the course of the experiment and was accompanied by a reduction in the rate of postreinforcement key pecking and an increase in the postreinforcement pause in key pecking. These effects on key pecking resulted in unprogrammed variations in the probability of reinforcement which may have been responsible for the induction of attack. In Experiment II, the attack-inducing properties of a constant-probability response-independent food schedule were compared to a periodic food schedule matched for overall rate of food delivery and to a no-food condition. In addition to attack, the spatial location of the subjects was monitored during each interfood interval. The periodic and aperiodic food schedules generated very different patterns of spatial location. Postfood attack was induced by both food schedules, although the constant-probability schedule induced attack in fewer birds. The no-food condition was not effective in inducing attack in any birds. These experiments indicate that intermittent food schedules without reductions in reinforcer probability are sufficient to induce attack in some pigeons, although not as effective as schedules with transitions in reinforcer probability.

Key words: schedule-induced attack, adjunctive behavior, probability of reinforcement, constant-probability food schedules, random-interval schedules, random-time schedules, spatial location, fixed-time schedules, aggression, White King pigeons

Food-deprived pigeons will attack a conspecific immediately following presentation of a small quantity of food. In a classic series of experiments on attack induced by a food schedule, Azrin, Hutchinson, and Hake (1966) found that pigeons vigorously charged and pecked at a conspecific target at the onset of extinction following a period of food delivery regardless of whether an operant response was required to produce the reinforcers. Subsequent studies (Cherek & Heistad, 1971; Dove, Rashotte, &

Katz, 1974; Flory, 1969; Gentry, 1968) have confirmed this post-food pattern of attack on a variety of intermittent food schedules.

It has been suggested that the postreinforcer pattern of schedule-induced attack and other schedule-induced behavior (for review see Staddon, 1977) results from a reduction in reinforcer probability following a reinforcer (Falk, 1971, 1977; Staddon, 1975, 1977; Staddon & Simmelhag, 1971). This suggestion is consistent with the fact that in previous studies the termination of the reinforcer invariably predicted a reduction in reinforcer probability. If a reduction in reinforcer probability following a reinforcer were necessary to induce attack, one would expect that constant-probability reinforcement schedules in which there is presentation and withdrawal of reinforcers, but invariant reinforcement probability, would be ineffective in inducing attack. On the other hand, if intermittent reinforcement without transitions in reinforcement probability were sufficient to induce attack then constant-probability schedules should effectively establish and maintain schedule-induced attack. The induction of postreinforcement attack by inter-

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mittent reinforcement alone would be consistent with suggestions by Azrin *et al.* (1966), Hutchinson (1973), and others (Gentry, 1968; Rilling, 1977; Rilling & Caplan, 1975) that the termination or withdrawal of a reinforcer induces aggression. This view is compatible with the proposal that there are aftereffects of reinforcers (Innis & Honig, 1979; Solomon & Corbit, 1974) and that schedule-induced behavior, including attack, may reflect motivational sequelae of reinforcers (Killeen, 1975).

Millenson, Allen, and Pinker (1977) and Lashley and Rosellini (1980) have examined this question with regard to schedule-induced polydipsia in rats and have found that constant-probability food schedules were effective in inducing polydipsia in fewer rats than schedules with variations in reinforcer probability. Allen and Weidinger (Note 1) have reported that all rats exposed to a constant-probability schedule acquired polydipsia, but for some acquisition was retarded and water intake per pellet was less than usually reported for schedules with reductions in food probability (e.g., Falk, 1961; Hawkins, Schrot, Githens, & Everett, 1972). Lashley and Rosellini (1980) also have found that a constant-probability food schedule was as effective as a periodic schedule when food deliveries were preceded by a signal. In effect, the signal introduced transitions in food probability since the probability of food was zero in the signal's absence. However, this latter finding has not been confirmed at present (Allen & Weidinger, Note 1). Taken together, these data suggest that schedules which incorporate reductions in probability of a reinforcer are more conducive to the generation of induced behavior. However, given the differences between schedule-induced drinking and schedule-induced attack in rats and pigeons (Hymowitz, 1971; Knutson & Schrader, 1975; Yoburn and Cohen, 1979a), these results may not extend to schedule-induced aggression. The present experiments determined whether intermittent delivery of food without variations or transitions in reinforcer probability is sufficient to establish and maintain schedule-induced aggression in pigeons.

EXPERIMENT I

Previous experiments that focused on the effects of reinforcement rate on schedule-induced attack in pigeons (e.g., Cohen & Looney,

1973; Flory, 1969) utilized reinforcement schedules that confound interrupted access to the reinforcer with a programmed reduction in reinforcer probability. In each study, including one that used variable-interval reinforcement schedules to induce attack (Dove *et al.*, 1974), the occurrence of the reinforcer signaled a programmed reduction in the probability of a reinforcer. Experiment I determined if interrupted access to food, without a programmed reduction in probability of food, is sufficient to induce attack in experimentally naive pigeons and, if so, whether attack follows the withdrawal of the reinforcer. Constant probability of reinforcement was arranged according to random-interval (RI) reinforcement schedules (Farmer, 1963; Millenson, 1963) in which the first response in a recycling time interval (T) was reinforced according to a preset constant probability (P). If T is set such that one response is emitted in each T -cycle, then the mean interreinforcement interval is T/P and the probability of a reinforced response is constant in time.

METHOD

Subjects

Six experimentally naive male White King pigeons were maintained at 75% (± 20 g) of their free-feeding weights. Wing and tail feathers were clipped regularly. Birds were housed in individual, visually isolated cages under a 16-hr light-dark cycle (lights on 0700 to 2300 hr). Birds had free access to water and grit in their homecages. Supplementary feedings of mixed grain were given following test sessions as required, so as to maintain stable deprived body weights.

Apparatus

A 33.0 by 35.9 by 34.9-cm metal and wood, black test chamber was placed inside a 63.5 by 109.2 by 102.2-cm black enclosure constructed of black wallboard and heavy black curtain. One wall of the enclosure had a 6.5-cm diameter opening opposite the 2.5-cm grid mesh door of the test chamber to allow video monitoring and recording of activity. An exhaust fan and white-noise generator partially masked extraneous noises.

The test chamber was equipped with a food magazine with a light (BRS/LVE 114-10) located behind a 5.1 by 5.8-cm opening centered on one 33.0 by 34.9-cm wall, 9.5 cm above the

grid floor. Chamber illumination was provided by two 1.6-W houselights mounted in the roof of the chamber behind a ground-glass shield. The houselights were located 3.8 cm in front of the wall of the chamber which housed the food magazine. A 2.5-cm diameter response key which could be transilluminated with a green light was centered 10.0 cm above the top of the food magazine opening. A key peck was defined as a response with a minimum force of .2N as measured by a Jonard dynamometer.

On the wall opposite the food magazine was a 12.5 by 16.5-cm Polacoat plastic diffusing screen suspended by two frame-mounted micro-switches (Micro Switch #311 SM 701T) (Looney, Cohen, & Yoburn, 1976). The screen was centered behind an 11.5 by 15.3-cm opening with the left edge of the opening 3.5 cm from the mesh door and the bottom edge 7.9 cm above the grid floor. The screen was covered with a seamless piece of Scotch Brand Magic Mending Tape in order to eliminate reflections and prevent scratches. Located directly behind the screen was a projector (Cohen et al., 1976) which could display on the screen a colored image of a conspecific (Target B; Looney et al., 1976). The image of the conspecific was 15.3-cm high with the head located at approximately the same height as a live White King pigeon standing in the test chamber. An attack was defined as a response on any point on the screen that had a minimum force of .1N as measured by a Jonard dynamometer. During sessions when the target image was unavailable, the screen was dark.

Standard electromechanical programming apparatus in an adjacent room recorded and scheduled experimental events. Food presentations were programmed by paper tapes punched by a PDP 8/I Digital Computer. The probability of a food delivery (P) was preset

and a random probability generator (FOCAL) was interrogated prior to each punch. The paper tapes were read into the programming apparatus via an eight-channel tape reader which advanced the tape each second. Each tape was a 30-min continuous loop.

Procedure

Magazine and key-peck training. The conspecific image was not present during this phase. Birds were trained to eat mixed grain from the food magazine and to peck the illuminated response key during the first two sessions. During each of the next three sessions, birds obtained 30, 2.5-sec food presentations on a continuous reinforcement schedule. All subsequent sessions in Experiment I consisted of 20, 2.5-sec food presentations.

Preliminary schedule training. During preliminary schedule training all birds were exposed to five sessions each of the following RI food schedules with the conspecific image unavailable: RI 5-sec ($P = .2000$), RI 10-sec ($P = .1000$), RI 20-sec ($P = .0500$), RI 30-sec ($P = .0333$). Three birds (P9100, P9115, P9042) were selected randomly and exposed to five sessions of RI 37.5-sec ($P = .0267$). The remaining three birds (P9254, P8356, P308) were exposed to five sessions of RI 60-sec ($P = .0167$).

A different paper tape programmed the availability of reinforcers during each session of preliminary training. For all RI schedules in Experiment I, a reinforcer was delivered only if a response occurred during the T -cycle in which it was made available. Unclaimed reinforcers were not stored until the next response. T equalled 1.00 sec for all RI schedules in Experiment I.

Target testing. Table I presents the testing schedule during target testing following preliminary training for all birds. Three birds

Table 1

Sequence of schedule conditions, number of sessions at each condition (parenthetical number), and the order of target image availability for all birds in Experiment I during target testing.

P9100	P9042	P9115	P9254	P8356	P308	Screen
RI 45 sec (20)	RI 45 sec (20)	RI 45 sec (20)	RI 90 sec (20)	RI 90 sec (20)	RI 90 sec (20)	No Image
RI 45 (20)	RI 45 (20)	RI 45 (20)	RI 90 (40)	RI 90 (20)	RI 90 (20)	Image
RI 45 (10)	RI 45 (10)	RI 45 (10)	RI 90 (10)	RI 90 (10)	RI 90 (10)	No Image
		RI 45 (10)	RI 90 (10)		RI 90 (10)	Image
		No-Food	No-Food		No-Food	
		Condition (20)	Condition (20)		Condition (30)	Image
		RI 45 (10)	RI 90 (10)		RI 90 (10)	Image

(P9100, P9115, P9042) were exposed to 50 sessions of RI 45-sec ($P = .0222$). The conspecific image was introduced into the chamber beginning with the 21st session of the RI 45-sec schedule and removed following the 40th session. The remaining three birds (P9254, P8356, P308) were exposed to 50 or 70 sessions of RI 90-sec ($P = .0111$). The conspecific image was introduced for 20 or 40 sessions beginning with the 21st session of the RI 90-sec schedule, and was unavailable during the following ten sessions. Birds in either the RI 90 or 45-sec schedule condition that had daily attack rates below an arbitrary criterion of .50 resp/min during exposure to the target were discarded from the experiment at this time.

All birds that attacked in excess of the criterion were re-exposed to the conspecific image and the RI schedule for ten sessions, followed by 20 to 30 sessions of a no-food condition. The no-food condition involved placing the bird in the chamber with the key covered and the target image present. No food was delivered during these sessions which were equated in length to the mean duration of the ten previous RI sessions. Animals were exposed subsequently to ten additional sessions of the RI schedule with the conspecific image available. Twenty-two paper tapes were used to program reinforcers on the RI 45- and 90-sec schedules with 11 tapes for each schedule. A different tape was used each session with a new random order determined every 11 sessions.

RESULTS

When reinforcers occur randomly in time on an RI schedule the frequency distribution of reinforcers as a function of time since a reinforcer has a geometric distribution which is approximated by an exponential distribution (Millenson, 1963). To evaluate the randomness of food deliveries in this experiment, the distribution of reinforcers as a function of time since a reinforcer for each bird for the 20 sessions prior to the introduction of the target was fit by the method of least squares (Lewis, 1966) to the generalized exponential equation:

$$y = ae^{bx}$$

where:

x = time since a reinforcer

b = obtained probability of a reinforcer

a = fitted constant

e = the base of natural logarithms

The fitted functions accounted for an average of 84% (range = 76 to 92%) of the variance in the actual reinforcer distributions for all birds. For two birds (P9115, P8356), however, a reinforcer reliably predicted a decrease in reinforcement probability. Both of these birds obtained fewer reinforcers immediately following a reinforcer than would be predicted by the fitted exponential function. For the remaining birds, there were no systematic deviations from an exponential process.

There were no systematic differences in overall rate or temporal distribution of key pecking following food between the birds exposed to the RI 45- or 90-sec schedule either before or after introduction of the target image. Figure 1 presents the overall rate of key pecking over the last 20 sessions prior to introduction of the target as a function of time since a reinforcer for each bird. The temporal distribution of key pecking was characterized by a brief but consistent increase in rate of key pecking over the first 30 sec following food. The mean rate of key pecking subsequently decreased throughout the remainder of the interfood interval for all birds. Relative to temporally defined reinforcement schedules with transitions in reinforcement probability [e.g., fixed-interval (FI); Dews, 1970], RI schedules supported stable operant responding during the interfood interval.

With target introduction, one bird exposed to the RI 45-sec schedule (P9115) and two birds exposed to the RI 90-sec schedule (P308, P9254) showed sustained levels of attack. One of these birds (P9254) did not initiate attack until the twentieth session with the target available. A fourth bird exposed to the RI 45-sec schedule (P9042) attacked the target three times during the fifth session with the target present, but did not attack further. Figure 2 presents the mean rate of attack (attack/session duration) as a function of successive sessions for the three birds that had daily mean attack rates greater than .50 resp/min during the first exposure to the image. Removal and reinstatement of the image were accompanied by a sharp decrease and subsequent increase in target contacts for all birds. When the food schedule was eliminated P9115 briefly attacked at a higher rate than during the food schedule and then stopped. For the remaining two birds, attack rate was higher during the last five sessions of the no-food condition than during the food schedule. Following the no-food condi-

Fig. 1. Mean rate of key pecking as a function of time since a food delivery (collected in 15-sec bins) pooled over the last 20 sessions prior to the introduction of the conspecific target for each bird. The unconnected filled symbols represent the mean rate of key pecking at greater than 285 sec following food.

tion, all birds attacked at rates comparable to those observed previously. Video monitoring of sessions indicated that birds charged and pecked at the head of the conspecific image. The topography and locus of attack are consistent with those reported during food schedules involving a programmed reduction in reinforcement probability following a reinforcer (e.g., Azrin et al., 1966; Cohen & Looney, 1973).

Figure 3 presents the mean postreinforcement pause (sec) in key pecking as a function of successive sessions for all birds. The pause was unaffected by the introduction of the conspecific image for the nonattacking birds (P9100, P9042, P8356) except for a transient increase for P9100. For the three attackers (P9115, P308, P9254), there was an increase in the duration of the pause during the same session in which attack began. This occurred on the first day with the target available for P9115 and P308 and on the twentieth day (arrow) for P9254. Removal of the target image (no-image condition) decreased pausing for P9254 and had no systematic effect on P9115 and P308. Reinstatement of the image increased the pause for P9115 and P9254 and had little effect on P308. Following the no-food condition, pausing increased for P9115 and P9254 and remained approximately the same for P308. In

spite of these changes in postreinforcement pausing, there were no systematic effects of target availability on the overall rate of key pecking for any bird.

Although there were differences between the three attackers in terms of the overall rate of attack, duration of the postreinforcement pause in key pecking, and the session during which the initial attack occurred, the development of the distribution of attack between reinforcers was comparable for the three attackers. Figure 4 presents response-rate distributions of attack and key pecking as a function of time since a food delivery for the first 20 (P9115, P308) or 40 (P9254) sessions with the image available. Initially, attack occurred following food as well as late in the long interfood intervals. With continued exposure to the target image, attack occurred predominantly postfood and at a lower rate following the postfood burst. The postfood pattern of attack persisted during subsequent phases of the experiment.

As shown in Figure 4 the initiation of attack was accompanied by a reduction in the average rate of postreinforcement key pecking (compare Figure 1). This decrease reflects, in part, the longer postreinforcement pause (Figure 3) that accompanied the initiation of attack. For

Fig. 2. Mean rate of attack (attacks/session duration) as a function of successive sessions for P9115, P308, and P9254. Image and No-Image conditions correspond to sessions in which the conspecific target was present and absent, respectively.

Fig. 3. Mean pause (seconds) in key pecking following a reinforcer as a function of successive sessions for each bird. Image and No-Image conditions correspond to sessions in which the conspecific target was present and absent, respectively. Key pecking did not occur in the No-Food condition (see text). The session during which attack was initiated by P9254 is indicated by the arrow.

the three nonattacking birds, target introduction did not affect the temporal distribution of key pecking.

DISCUSSION

Three of six experimentally naive pigeons in this experiment developed sustained attack on a conspecific target image during exposure to RI food schedules. The effectiveness of the RI 45- and 90-sec schedules in inducing attack was approximately equal. The development of attack on constant-probability schedules was comparable to that observed on other schedules, although only 50% of the birds attacked as compared with approximately 70% or more in studies using schedules with transitions in reinforcer probability and two-dimensional targets (Looney et al., 1976; Yoburn & Cohen, 1979a). In both cases, a predominantly post-reinforcer pattern of attack developed. These results indicate that a programmed reduction in reinforcer probability following a food delivery is not necessary to induce attack and suggest that attack is related to the intermit-

tent availability of a reinforcer, and not to a signaled transition in its probability.

The results of this experiment do not rule out the possibility that subject-imposed departures from the programmed reinforcement probability may have been responsible for the establishment of attack. The decrease in the rate of postreinforcement key pecking and the increase in the postreinforcement pause which developed concurrently with the initiation of attack resulted in a reduction in the obtained rate of reinforcement immediately following a reinforcer. During the 20 sessions prior to the introduction of the target image, average reinforcement rates during the first 15-sec following food were .51, .49, and .48 reinforcer/min for P9115, P308, and P9254, respectively. During the first 20 sessions with attack, rate of reinforcement decreased to .30, .21, and .32 reinforcer/min, respectively, during the first 15 sec following food. For P9254 the rate of reinforcement 15 sec following food during the first 19 sessions with the target available prior to the initiation of attack was essentially unchanged

Fig. 4. Mean rate of key pecking (lines, left ordinate) and attack (triangles, right ordinate) as a function of time since a food delivery (collected in 15-sec bins) for the first 20 (P308, top row; P9115, second row), and 40 (P9254, bottom two rows) sessions with the target present. Each graph represents the pooled data from five successive sessions. Successive blocks of five sessions are presented left to right. The unconnected filled symbols represent the rate of attack and key pecking at greater than 285 sec following food.

(.53 reinforcer/min). In short, attack and subject-imposed reductions in reinforcement rate developed concurrently. Whether attack engendered the decrease in reinforcement rate following food by precluding key pecking, or whether the unprogrammed reduction in reinforcement rate following food induced attack is unclear and will be examined further in the second experiment.

A traditional way of assessing the effectiveness of a schedule to induce attack is to com-

pare the rate of attack during the food schedule to that during a no-food condition (Azrin *et al.*, 1966; Looney *et al.*, 1976; Yoburn & Cohen, 1979a, 1979b). If attack rate is greater during the food schedule than in its absence, then attack is considered to be schedule induced. In this experiment, attack rate was greater when the food schedule was *removed* than when it was present for two of the three attackers. In these cases, the RI schedule may have simply suppressed attack. An alternative possibility is

that exposure to a food schedule prior to the introduction of the target image was necessary for attack to occur both during the food schedule and the no-food condition. In other words, the schedule may have had the dual effect of inducing attack and then suppressing it once established, perhaps as a result of competition between key pecking and attack. In any case, long-term perseveration of schedule-induced attack in the absence of a food schedule was also observed by Looney et al. (1976) and, on the basis of their results, would be expected to decrease with further exposure to the no-food condition.

EXPERIMENT II

The first experiment indicated that a reduction in reinforcement probability was not necessary to establish a postfood pattern of attack in some pigeons. This conclusion is tentative, however, since an unprogrammed reduction in reinforcement probability attributable to pausing in operant responding may have contributed to the induction of attack. The use of response-dependent constant-probability schedules also may account for the failure of some birds to attack, since the high steady rate of operant responding supported by the RI schedule may have competed with a tendency to engage in schedule-induced attack. This could be why fewer birds exhibited sustained attack on RI schedules than on schedules with signaled transitions in reinforcer probability (e.g., Looney et al., 1976). One way of avoiding or minimizing such problems is to use a random-time (RT) food schedule in which the probability of a food delivery is constant and independent of behavior. With this arrangement there is no explicitly reinforced operant response to compete with attack.

The present experiment used an RT schedule to evaluate the effectiveness of constant-probability food schedules to induce attack. One group of pigeons was exposed to a fixed-time (FT) 90-sec food schedule in which the occurrence of food signaled a reduction in food probability. Another group was exposed to an RT 90-sec food schedule which had the same mean rate of food presentation but without such reductions in probability. A third no-food group was tested to determine if exposure to food itself was necessary for attack to occur. In order to evaluate if these conditions differ-

entially affect nonaggressive behavior, the temporal organization of spatial location in the test chamber, as well as aggressive behavior, was recorded. Finally, since it has been shown that a longer period of food delivery can facilitate attack (Azrin et al., 1966), the duration of the food delivery was increased in this experiment so that the likelihood of attack in the schedule conditions would be enhanced.

METHOD

Subjects

Eighteen male, experimentally naive, White King pigeons were maintained at 75% (± 20 g) of their free-feeding weights and housed as described in Experiment I.

Apparatus

The apparatus was the same as that used in Experiment I except for several modifications. First, the response key was covered and a photodetector system was installed in the hopper to record eating. Second, two infrared photo-beam detector systems were installed to monitor the bird's location during test sessions (Figure 5). Two light sources were mounted opposite the mesh chamber door behind one wall of the enclosure. The collimated light emitted from the sources was filtered (Kodak gelatin #87A) so that only infrared wavelengths invisible to the pigeon (Donovan, 1978) were passed. The two beams were focused on the front (hopper-wall) and rear (target-wall) infrared photodetectors located 10.2 cm above the mesh floor and 8.3 cm from the front or rear walls. Both sources were positioned so that the light beams were parallel to the floor and the front and rear walls. Pilot experiments indicated that the beams reliably and accurately detected when a pigeon of virtually any size was located in the front or rear of the test chamber. In addition, animals could easily stand between the beams. This allowed categorization of the pigeon's location into three classes: front (hopperwall), middle, and rear (target wall) as a function of time since a food delivery.

The asymmetrical overhead lighting required for the projected target image in Experiment I was not appropriate for this experiment since spatial location was being recorded and unwanted biases in the birds' location preferences in the test chamber might have been introduced. Therefore, six symmetrically

Fig. 5. Schematic diagram of the test chamber and enclosure used during Experiment II. The wall with the hopper opening was defined as the front of the chamber and the wall with the target screen was defined as the rear of the chamber.

located 1.6-W houselights were illuminated and an equal-size color print of the target image used in Experiment I was mounted on the projection screen. As in Experiment I, an attack was defined as a response that had a minimum force of .1N on any point on the screen. During sessions when the photograph was not present, the rear wall on which the target was mounted was replaced by a smooth black wall.

Procedure

Each bird was randomly assigned to one of three groups (RT, FT, NF). In the absence of the conspecific photograph, birds in Groups RT and FT were trained to eat from the hopper in one session. Beginning with the next session, birds in Groups RT and FT were exposed to 25 daily sessions of an RT or FT 90-sec food schedule, respectively. The RT schedule delivered food independently of the subject's behavior, with the probability of a food delivery (P) equal to .0111 in each 1-sec T -cycle throughout each session. Twenty-two, 30-min continuous-

loop tapes were generated by the computer to control the delivery of food for the RT group. The tapes were used sequentially so that three tapes had to be used twice. The FT schedule delivered food every 90 sec independently of behavior. Each RT and FT session consisted of 16, 7-sec food deliveries with each session ending with the 16th food presentation. In order to insure regular eating, all birds in the RT and FT groups were given five, 7-sec food deliveries spaced approximately 5-sec apart prior to the first RT or FT session. The conspecific photograph was introduced into the test chamber on the 16th session and remained there for the final ten sessions. The photobeam system in the food magazine recorded the insertion of the bird's head into the magazine during each food delivery, but food deliveries were not timed from the moment of head insertion.

The remaining six birds in Group NF (no food) were treated identically to the RT and FT groups except that the hopper and hopper

light were disconnected and no food was presented in the test chamber at any time. Pigeons in this group were placed in the test chamber during the first session for an amount of time equal to the mean duration of hopper training for the FT group. These birds were then exposed to 25 sessions equated in duration to the FT group. The conspecific photograph was introduced into the test chamber during the 16th session and remained there for the final ten sessions.

The location (front, middle, rear) of each animal during a test session was recorded as the amount of time (in 100ths of a min) that a photobeam was interrupted or neither beam was interrupted (middle) during successive 15-sec bins following a food delivery. The location data are expressed as relative time, which is the total amount of time in a bin for each location, divided by the sum of time in all three locations for that bin. The number of attacks was also recorded in 15-sec bins following a food delivery. For birds in the NF group, these data were recorded as if a food delivery had occurred every 90 sec.

RESULTS AND DISCUSSION

The average rate of food deliveries over the 25 sessions of the experiment was comparable for the RT and FT groups (Group RT $x = .62$ reinforcer/min, range = .62 – .64; Group FT $x = .65$ reinforcer/min, range = .65 – .66). The distributions of reinforcers as a function of time since a reinforcer for each bird in the RT group were well described by fitted exponential functions which accounted for a group mean of 89% (range = 84 to 92%) of the variance in the data. There were no systematic deviations from an exponential process for any of the reinforcer distributions for any bird. In addition, following the first day of schedule training, birds in the RT and FT groups collected all food deliveries, except that P9188 (FT group) missed the first food delivery in all but two sessions and P8893 (RT group) missed one food delivery during the sixth session.

Figure 6, presents the mean distributions of relative time in the front, middle, and rear of the test chamber as a function of time since a food delivery over the five sessions prior to introduction of the conspecific target, for each bird in the three groups. When food was either unavailable (NF) or did not signal a reduction in food probability (RT), birds

nondifferentially distributed their time in each location with respect to time since a hypothetical (NF) or a real (RT) food delivery. On the other hand, when the occurrence of food signaled a reduction in probability of food (FT), all birds exhibited a marked trend in the relative amount of time spent in the front of the chamber as a function of time since a food delivery. All but P9242 moved away from the front of the chamber following food and spent an increasing amount of time in the front as the next food delivery approached. P9242 displayed the reverse pattern, spending more time in the rear of the chamber as the next food delivery approached. For birds in the RT and FT groups, the distribution of time in the middle and rear of the chamber tended to covary and was inversely related to the distribution of time in the front, although for P9242 (FT) the time in the middle was relatively invariant during the interfood interval.

In order to quantify the trends in location during the interfood interval prior to target introduction, the data during the first 90 sec following food for each bird were fit by the method of least squares (Lewis, 1966) with the general equation for the logarithmic curve:

$$y = a \log x + b$$

where:

x = time since a reinforcer

b = fitted constant

a = fitted regression coefficient

Only the data from the first six 15-sec bins were included so that the number of data points used to fit the function would be the same for all groups. The mean group regression coefficients (.2297, .0225, .0048 for the FT, RT, and NF groups, respectively) were significantly different from zero (Li, 1964) for the FT group [$F(1,24) = 50.96, p < .05$] but not for the RT [$F(1,24) = 1.30, p > .05$] or NF groups [$F(1,24) = .01, p > .05$].

The distribution of time in the front of the chamber during the interfood interval for the RT and FT groups is comparable to the temporal distribution of operant responding on analogous response-dependent schedules (i.e., RI and FI). The flat distributions following food for the RT birds were similar to the distributions for key pecking for the birds on RI schedules in Experiment I prior to target introduction. Likewise, the relative time distributions in the front of the chamber for FT

Fig. 6. Mean relative time in each location (front, middle, rear) of the chamber as a function of time since a food delivery (collected in 15-sec bins) for each bird over the last five sessions prior to the introduction of the conspecific target. Each graph represents the pooled data from five successive sessions. The unconnected filled symbols for the RT group represent the mean relative time spent in each location at greater than 285 sec following food.

birds were comparable to those for key pecking on FI schedules (e.g., Dews, 1970) for all but one bird. For that bird the function for the rear of the chamber was comparable to that observed for key pecking on FI schedules. In general, these data are consistent with other experiments which have shown that a response requirement is not necessary for behavior to be organized with regard to the temporal distribution of reinforcers (Fenner, 1980; Killeen, 1975; Killeen, Hanson, & Osborne, 1978; Staddon & Ayers, 1975; Staddon & Simmelhag, 1971) and suggestions that the allocation of time in different areas of the test chamber may be a fundamental determinant of operant performance (Baum & Rachlin, 1969). In addition, these data are in agreement with suggestions that the local rate of operant responding is relatively constant (Rachlin, 1973; Staddon, 1977), but that the time allocated to respond-

ing varies during the interfood interval. If a constant response rate were multiplied by the temporal distribution of time in the front of the chamber for the RT and FT groups the resulting functions would be similar to the response patterns observed for operant responding on RI (Experiment I; Farmer, 1963; Milenson, 1963) and FI schedules (Dews, 1970; Ferster & Skinner, 1957), respectively.

With introduction of the conspecific target for 10 sessions, all birds in the RT and FT groups contacted the target, whereas only three birds in the NF group did so. Five birds in the FT group and four in the RT group attacked during each session, whereas only one bird in the NF group attacked with the same regularity. The daily rate of attack exceeded .50 resp/min for all five daily attackers in the FT group and for none of the birds in the NF group. Three (P183, P8851, P9288) of the four daily

attackers in the RT group attacked in excess of .50 resp/min. Attack rates were not significantly different among groups over the first five sessions with the target (Kruskal-Wallis $H = 5.11$, 2 df , $p > .05$), although they were significantly different by the final five sessions ($H = 10.26$, 2 df , $p < .05$). Subsequent one-tail Mann-Whitney U tests revealed that the NF group attacked at a lower rate than the FT group ($U = 1$, $p < .05$) and the RT group ($U = 4$, $p < .05$), whereas the RT and FT groups did not differ ($U = 7$, $p > .05$). The method of adjusted significance levels (Kirk, 1968) was used for all such a posteriori tests.

There was substantial variability in attack rate both within and across birds and sessions, which makes it difficult to evaluate the maintenance of attack in each session among groups. Figure 7 presents the percentage of interfood intervals with at least one attack as a function of successive sessions for each bird. This measure is relatively insensitive to changes in absolute attack rate and is more stable than attack rate across sessions. Only one bird in the NF group attacked during more than one session, whereas five birds in the FT group attacked during each session. Although four birds in the RT group attacked during each session, one of these birds (P8500) attacked

only during the period prior to the first food delivery during Sessions 22 to 24. This same bird failed to attack in excess of the .50-response/min criterion during each session. Over the first five sessions, the percentage of interfood intervals with at least one attack was significantly different among groups (Kruskal-Wallis $H = 7.00$, 2 df , $p < .05$). Subsequent one-tail comparisons between individual groups revealed that the FT group was different from the NF group (Mann-Whitney $U = 4$, $p < .05$) and the RT group ($U = 5$, $p < .05$), although the NF group was not different from the RT group ($U = 11$, $p > .05$). By the final five sessions with the target available, there were still significant differences among groups in terms of percentage of interfood intervals with an attack ($H = 11.85$, 2 df , $p < .05$), but subsequent comparisons indicated that the NF group attacked during fewer interfood intervals than both the FT group ($U = 1$, $p < .05$) and the RT group ($U = 3$, $p < .05$), and that the RT and FT groups did not differ ($U = 7$, $p > .05$).

For the five sustained attackers in the FT group and the three in the RT group there was a burst of attack following a food delivery (Figures 8 and 9). The distribution of attack for the one bird in the NF group that attacked

Fig. 7. Percentage of interfood intervals in which there was at least one target contact as a function of successive sessions with the conspecific target available for each bird in the FT, RT, and NF groups.

Fig. 8. Mean rate of attack as a function of time since a food delivery (collected in 15-sec bins) during the first (left panel for each subject) and second (right panel) five sessions with the conspecific target available for the five sustained attackers in the FT group. Each graph represents the pooled data from five successive sessions.

during each session was flat (not shown). Birds in the FT group attacked mostly following a food delivery during the first and second blocks of five sessions, although attack during the first two sessions was not predominantly postfood. Two birds (P9547, P8568) showed substantial attack late in the interfood interval, although attack was maximal following food. Attackers in the RT group attacked following a food delivery and late in the long interfood intervals. By the final five sessions, the postfood burst of attack for the RT birds was less intense than for the FT birds. The rate of attack for all but one of the FT birds (P8556) during the first 15-sec following food exceeded the postfood rate for each of the RT birds by the final five sessions. Similarly, Allen and Weidinger (Note 1) have found that the postfood

Fig. 9. Mean rate of attack as a function of time since a food delivery (collected in 15-sec bins) during the first (left panel for each subject) and second (right panel) five sessions with the conspecific target available for the three sustained attackers in the RT group. Each graph represents the pooled data from five successive sessions. The unconnected filled symbols represent the mean attack rate at greater than 285 sec following food.

burst of drinking typical of schedule-induced polydipsia in rats is suppressed in many animals by RT schedules. The bursts of attack late in the long intervals represent isolated incidents associated with a small number of long intervals. (Long interfood intervals are less likely than short intervals on a random schedule (Millenson, 1963), since the frequency distribution of interval length is an exponentially decreasing function.) The postfood attacks and attacks during long intervals indicate that not only does termination of food generate a burst of attack, but so does a long period of no food.

Following target introduction, the spatial-location functions (not shown) for most birds were similar to those presented in Figure 6, with some exceptions. All the attackers in the FT group showed the same trends as prior to target introduction, but the slopes of the functions were steeper. P9242 of the FT group reversed its previous pattern and spent more time in the front as the time for the next food delivery approached. The nonattacker in the FT group spent much less time in the rear of the chamber with the target present, which sug-

gests that the target was being avoided. The sustained attackers in the RT group went to the rear of the chamber following food, which reflected the postfood attack burst. The introduction of the target did not affect location for the two nonattackers in the RT group, and resulted in an increase in time in the rear for the low-rate attacker (P8500). The five birds in the NF group which did not attack during each session all increased the time spent in the front of the chamber and decreased time in the rear, which indicates that the target was not a neutral stimulus. The attacker increased time in the rear. All of the spatial location functions remained flat for the birds in the NF group.

The establishment of attack by response-independent constant-probability food schedules indicates that a local reduction in probability of a food presentation is not a crucial feature of attack-inducing food schedules for some pigeons. These results indicate that the unprogrammed reductions in reinforcement probability that developed concurrently with attack on RI schedules in Experiment I were not critical for the induction of attack. However, as in Experiment I, only 50% of the birds exposed to the random food schedule showed sustained attack, despite the increased size of the food delivery and the elimination of a response contingency. Apparently, the reduced effectiveness of random food schedules is related to the programmed constant probability of food, at least with a two-dimensional target. Perhaps a live target would increase the effectiveness of random food schedules to induce attack, since virtually all pigeons will attack a live target on a periodic food schedule (Azrin et al., 1966).

GENERAL DISCUSSION

The results of these experiments indicate that intermittent food is a sufficient condition to induce attack in some pigeons and that reductions in probability of a food delivery are not necessary. In general, there was a burst of attack following a food delivery regardless of whether or not food signaled a period of no food, although in Experiment II the rate of postfood attack for the RT group was less than for the FT group. This postfood burst of attack is consistent with suggestions that there are aftereffects of reinforcement (Innis & Honig, 1979; Solomon & Corbit, 1974) and that schedule-induced attack is induced by interrupted access to or the withdrawal of a reinforcer

(e.g., Azrin et al., 1966; Hutchinson, 1973). The present results also support the idea that schedule-induced behavior may reflect the elicitation of arousal by the reinforcer (Killeen, 1975). It should be noted that the postreinforcer attack seen in these experiments may be specific to food reinforcers. Campagnoni, Cohen, and Yoburn (Note 2) have found that although schedule-induced attack occurs on periodic water schedules, there is no postwater burst of attack for most animals. These results suggest that the temporal distribution of attack in the interreinforcer interval depends on a variety of factors including the type of reinforcer.

Although constant-probability food schedules did induce attack in some birds, the present results suggest that they are less effective in establishing attack than schedules with transitions in reinforcer probability following a food delivery. Whereas schedules with transitions were effective in establishing attack in five of six birds in Experiment II and approximately 70% or more in previous experiments using a two-dimensional target (Looney et al., 1976; Looney & Dove, 1978; Yoburn & Cohen, 1979a), constant-probability schedules were effective in 50% (six of twelve) of the birds in these experiments. In this respect, the results of the present experiment are similar to those reported by Millenson et al. (1977) and Lashley and Rosellini (1980), who found that schedules with transitions in reinforcement probability were more effective in establishing schedule-induced polydipsia in rats than constant-probability food schedules. One possible explanation of these results is that the greater-than-zero probability of reinforcement following a reinforcer may degrade the impact of the food withdrawal to such a degree that vigorous attack and polydipsia are established in fewer animals. This might explain the less robust postfood burst of attack for the three RT attackers relative to the FT birds. Perhaps constant-probability schedules in which the overall probability of a food delivery was lower than in the present experiment would be as effective as periodic schedules with the same mean rate of food in establishing attack and other induced behavior. A second possibility is that both response-dependent and response-independent constant-probability food schedules maintain behavior which successfully competes with schedule-induced behavior in some animals. This second possibility is consistent with

Lashley and Rosellini's (1980) finding that RT and FT schedules are equally effective in inducing polydipsia in rats when random food deliveries are preceded by a 5-sec signal. This signal might have reduced competition between polydipsia and prefood behavior by confining prefood behavior to the period of the signal.

If attack is induced by the termination of food, then one would not expect attack to occur at other times in the interfood interval. Muller and Cheney (Note 4) and Flory and Smith (Note 3) have reported that pigeons will exhibit a burst of attack when a target is presented for a limited time at a considerable temporal distance from food withdrawal. In their experiments the onset of the target apparently became a signal that food was unavailable, and therefore that the schedule of reinforcement was not in effect. It is possible that the withdrawal of the schedule as signaled by the target served to induce the burst of aggression in much the same way that the withdrawal of food induced a burst of attack in these experiments. Their finding that attack was typically maximal following target presentation is consistent with this interpretation, as is Rilling and Caplan's (1975) finding that termination of a stimulus associated with a schedule of food reinforcement will be accompanied by a burst of attack in pigeons. However, the occurrence of attack during the long interfood intervals (in addition to postfood attack) in the present experiments, suggests that not only does food withdrawal induce attack, but that a period of no food within the context of intermittent food is also effective. It is possible that these attack bouts were related to a "subjective withdrawal" of the food schedule. In other words, if food does not occur for some period of time, the bird perceives that the schedule has been discontinued and this induces attack. Krebs, Ryan, and Charnov (1974), studying foraging in captive black-capped chickadees, found that birds will leave a feeding patch after a certain amount of time has passed since the last piece of food was obtained. The attack during the long interfood intervals may be related to this tendency to leave a feeding area following a period of no food.

Finally, the failure of birds in the NF group in Experiment II to show sustained attack during each session indicates that exposure to a food schedule is necessary for attack to be in-

duced. Only two birds in the NF group contacted the target during the first session, compared with four and five birds in the RT and FT groups, respectively. This indicates that prior exposure to intermittent food was an important factor in determining a bird's initial reaction to the target. Furthermore, the food schedules maintained attack for a total of eight birds whereas the no-food condition was not effective for any. These results imply that the continuation of attack for two birds in Experiment I and some birds in other experiments (Looney *et al.*, 1976; Yoburn & Cohen, 1979a, 1979b) during a no-food condition was related to prior schedule experience. The failure of a bird to reduce or stop attacking when a food schedule is withdrawn does not indicate that attack was not established by the schedule originally. Therefore, once attack has been induced, a no-food condition may not accurately indicate the degree to which the attack is schedule-induced.

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