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CONDITIONING OF THE AGGRESSIVE BEHAVIOR OF PIGEONS BY A FIXED-INTERVAL SCHEDULE OF REINFORCEMENT[1]

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Operant reinforcement of aggression was studied in food-deprived pigeons by delivering food for attacks against a target pigeon. The food was delivered according to a fixed-interval schedule and attack behavior was recorded automatically. Attack could be conditioned and extinguished, and the proportion of time spent in attack was a direct function of the frequency of reinforcement of the attack. The fixed-interval schedule produced an increasing rate of attack during the interval between food reinforcements. This positive curvature was an inverse function of the duration of the interval. The findings revealed that the duration and temporal patterning of the complex social behavior of attack can be influenced in a substantial and predictable manner by the schedule and frequency of operant reinforcement.

Aggressive behavior is influenced by many factors such as species differences, hormones, electrical or chemical stimulation of the brain, conditions of rearing, age, seasonal variations, sex, and the external coloration, form, posture, and behavior of the target (see general reviews by Scott, 1958; Hinde, 1966; Lorenz, 1966; Carthy and Ebling, 1964). In some aggressive interactions, considerable operant reinforcement for the aggression seems to result and would seem to be responsible for maintaining it; *e.g.*, territoriality fights, the prey-predator relation, nest defense, mating season competition, overcrowding, and emergence of a dominance hierarchy. Experimental evidence exists to show that aggression can be conditioned. Classical conditioning has been obtained by Thompson and Sturm (1965) of the aggressive display of Siamese fighting fish. Operant conditioning of attack has been obtained by Reynolds, Catania, and Skinner (1963) using food reinforcement with pigeons, and by Ulrich, Johnston, Richardson, and Wolff (1963) using water reinforcement with rats. Similarly, Azrin, Hutchinson, and Hake (1967) found that the biting attack of monkeys could be conditioned and maintained by a shock-avoidance procedure, confirming a previous report (Miller, 1948) that attack between rats could be conditioned by a shock-escape procedure. Yet to be investigated is whether such a complex social behavior as attack will be influenced in a predictable way by specific reinforcement variables such as the schedule and frequency of reinforcement. Although attack behavior may be greatly influenced by its operant consequences in the naturalistic environment, definitive answers to the above questions would seem to require investigation in an environment in which the independent variables can be precisely manipulated, extraneous factors held constant, and recording reliability increased. The present study attempted to answer these questions in a laboratory situation by delivering food as a reinforcement for attack according to a fixed-interval schedule. This schedule, which has been studied extensively with less complex responses, produces a distinctive and predictable temporal patterning of response (Ferster and Skinner, 1957, Chapter 5).

METHOD

Subjects

Four naive male White Carneaux pigeons weighing about 550 g served. Two were the experimental subjects; the other two served as targets. Each target bird was assigned exclusively to a particular experimental bird. One additional pair was discontinued because of a relatively high incidence of attack before the

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attempt to reinforce the attacks. The target birds were maintained at their free-feeding weight, and experimental birds at 80% of their free-feeding weight.

Apparatus

The technique for automatically recording attack has been described elsewhere (Azrin, Hutchinson, and Hake, 1966). Briefly, the target pigeon was located in a restraining box at the rear of an experimental chamber which was 30-in. long. When a force of 125 g or more was exerted against the target bird, the contacts of an electrical switch on the restraining box were closed. The closure activated timers and other recording devices providing a measure of the duration of attack by the experimental bird. This recording procedure provides a measure of duration, not number. Food reinforcement was made available to the experimental bird by raising a food tray into an opening centered on the front panel of the chamber. The target bird could not obtain the food because of the distance between it and the food-tray opening. During each presentation of the reinforcer, the food tray was elevated and illuminated, the usual overhead illumination was extinguished, and a tone sounded. A photocell arrangement in the food-tray opening made it possible to hold the food tray in the elevated and accessible position until the bird inserted its head into the opening. The tray was lowered into an inaccessible position 2 sec after the photocell interruption. Visual observation was possible through a one-way glass on the side of the chamber and by means of a closed-circuit television camera at the rear.

Procedure

Table 1 shows the sequence of conditions, number of sessions, and session duration for each condition. The number of sessions given is for one of the pigeons; the number for the other pigeon differed only by one or two sessions.

Condition 1 provided a measure of the operant level of attack against the target pigeon when food was not delivered, either on a response-contingent or non-contingent basis. Condition 12 provided a measure of extinction and was a redetermination of Condition 1.

Conditions 2 and 4 ascertained how much attack would be produced or "elicited" by food delivery that was not contingent on any behavior. Previous findings (Azrin *et al.*, 1966) revealed that the delivery and termination of food could elicit attack under some circumstances. By alternating this non-contingent procedure with the contingent food delivery of Conditions 3 and 5 (ABAB design), the specific effect of the response-reinforcement contingency could be evaluated, since the frequency and number of food deliveries were otherwise identical.

Conditions 5 to 11 provided a measure of the effects of the fixed-interval schedule of reinforcement of attack behavior employing seven fixed-interval values from 30 sec to 60 min. Food was delivered for the first attack that occurred after the lapse of the designated time interval. The intervals were timed from

Table 1

Experimental Design

Condition	*No. of Sessions*	*Session Duration*
1. No food delivered	2	15 min
2. Food delivered every 30 sec, not contingent on behavior	17	30 food deliveries
3. Attack produced food delivery—30-sec FI schedule	30	30 food deliveries
4. Food delivered every 30 sec, not contingent on behavior	21	30 food deliveries
5. Attack produced food delivery—30-sec FI schedule	15	30 food deliveries
6. Attack produced food delivery—1-min FI schedule	11	30 food deliveries
7. Attack produced food delivery—2-min FI schedule	9	30 food deliveries
8. Attack produced food delivery—4-min FI schedule	11	30 food deliveries
9. Attack produced food delivery—10-min FI schedule	8	12 food deliveries
10. Attack produced food delivery—20-min FI schedule	8	6 food deliveries
11. Attack produced food delivery—60-min FI schedule	16	2 food deliveries
12. No food delivered	6	120 min
13. Attack produced food delivery—1-min FI schedule	11	30 food deliveries

the termination of the previous food delivery, or, in the case of the first interval, from the start of the session. The 1-min fixed-interval schedule was imposed a second time (Condition 13) to determine the degree to which the performance at that value would be recovered. Similarly, Condition 4 provided a redetermination of the attack behavior during the 30-sec fixed-interval schedule.

The sessions lasted 15 min during Condition 1 and 2 hr during Condition 12; no food was delivered in either. All other sessions were terminated by the 30th food delivery or by the first food delivery after the lapse of 2 hr, whichever occurred first. The sessions were conducted daily except when the condition of the target bird made it inadvisable. Only two sessions were conducted during Condition 1; at least six were conducted for each of the other conditions.

RESULTS

As in the previous study (Azrin *et al.*, 1966) using this method of measuring attack, systematic visual observation produced a record that corresponded closely with the automatic record. The aggression did not consist of a discrete pecking movement; rather it resembled the "natural" aggression seen between pigeons. The pigeons usually rushed at the target bird, pulling at its feathers and pecking at its head and often being attacked in turn by the target bird. The birds often struck the target with their wings and were in constant "agitated" motion during the attack. Some

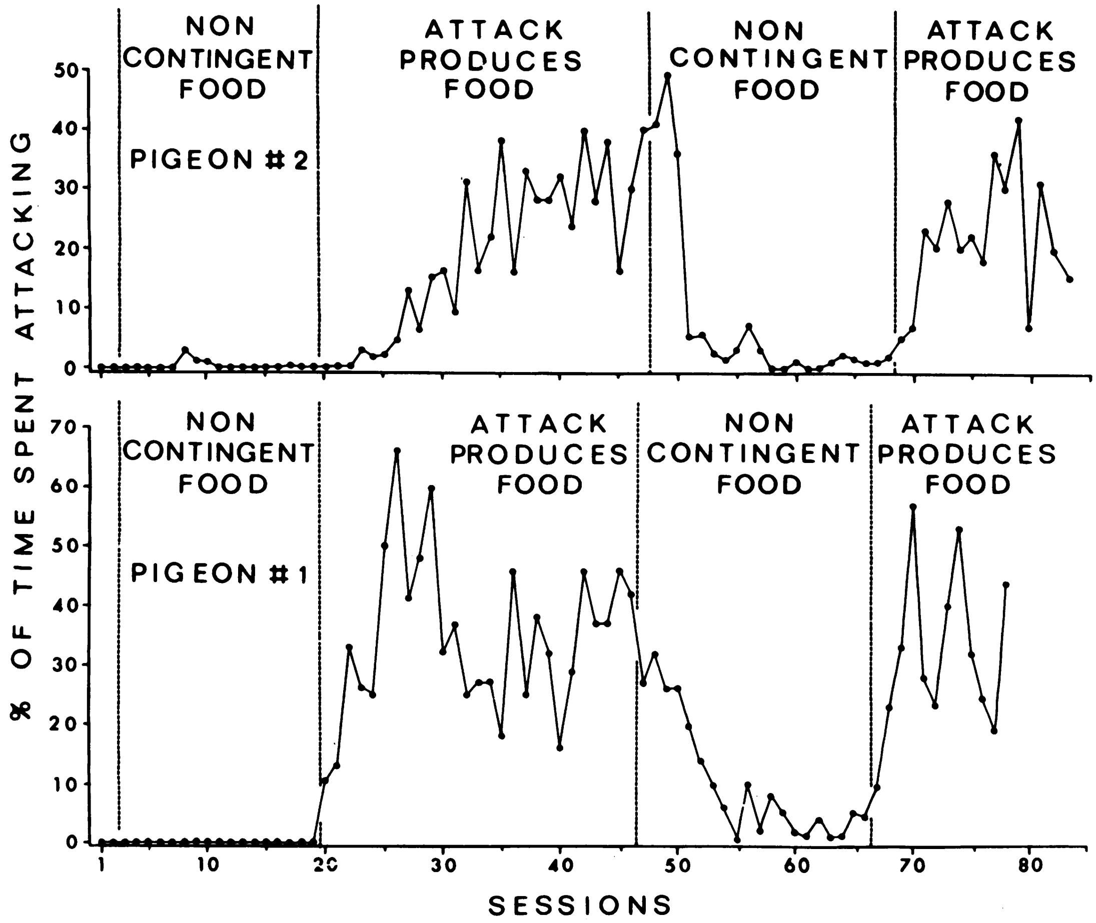

Fig. 1. Percentage of the session duration spent in attack against a target pigeon by Pigeon #1 and #2. During the first two sessions, no food was delivered. Under Non-Contingent Food, the food was delivered to the pigeon every 30 sec independently of its behavior. Under Attack Produces Food, the food was delivered for attacks according to a 30-sec fixed-interval of reinforcement.

aspects of the aggression persisted in spite of their irrelevance or interference with the receipt of food during reinforcement. For example, the birds often pulled at the target birds' feathers even though pulling could not be reinforced.

The attack often continued for several seconds after the food tray was made available in spite of the distinctive stimulus changes (overhead lights extinguished, onset of loud tone) that accompanied the food availability. In preliminary studies, this failure to discontinue attack caused the pigeons to miss several food deliveries, since the food tray was available for only 3 sec. The problem was solved in the present experiment by maintaining the food tray in the accessible position until the pigeon was in a position to eat from it.

Figure 1 shows the percentage of time spent in attack when no food was delivered, when it was delivered on a non-contingent basis, and when on a contingent basis (Conditions 1 to 5). The pigeons did not attack the target during sessions 1 and 2 when no food was delivered. When food was delivered independently of behavior (Non-Contingent, sessions 3 to 19), the pigeons usually attacked less than 1% of the time. The attacks increased to about 35% of the session for both subjects when attack produced food according to the 30-sec fixed-interval schedule. When the food was again delivered independently of behavior (about session 48), the attack gradually declined to less than 5% but increased to the previous level when food was again delivered for the attacks. The duration of attack was fairly variable between sessions; the coefficient of variation for the last 10 sessions of the two contingent procedures was 0.20 and 0.28 for S-1 and 0.20 and 0.38 for S-2. The coefficient of variation calculated from the data of studies of fixed-interval reinforcement of simpler responses has usually been less, *e.g.*, 0.08 for Azrin and Holz (1961, Fig. 1).

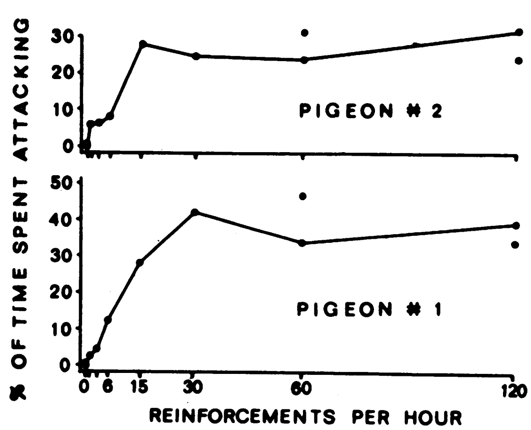

Fig. 2. Percentage of the session duration spent in attack by Pigeons #1 and #2 against a target pigeon as a function of the frequency of food reinforcement of the attack response. The reinforcement was delivered according to a fixed-interval schedule. Each data point is based on the last five sessions of exposure to a designated reinforcement frequency. The points not connected by the line are redeterminations.

Figure 2 shows the percentage of time that the pigeons attacked during the different values of the fixed-interval schedule of food reinforcement. Almost no attack occurred when no food reinforcement was delivered (zero reinforcements per hour in the figure). The time spent in attack increased as a direct function of the frequency of reinforcement, reaching a maximum of about 30 to 40% at about 30 reinforcements per hour. Further increases of the rate of reinforcement did not change the percentage of time spent in attack. The second determination at zero reinforcements per minute was almost identical to the first. The redeterminations at 60 and 120 reinforcements per minute did not differ from the initial ones enough to alter the general nature of the relation.

Figure 3 illustrates how attack was distributed during the interval between reinforcements for the 1-min fixed-interval reinforcement schedule. Each data point shows the percentage of time that the bird spent attacking during each of 10 intervals of 6 sec and is taken from timer readings of the attack behavior during the last five sessions of exposure to that schedule. The pigeons seldom attacked immediately after reinforcement, but immediately before reinforcement were engaged in almost continuous attack, about 90% of the time for one pigeon and 65% for the other. The duration of attack in the figure was a direct function of the time since the previous reinforcement.

Figure 4 shows the degree of positive curvature between reinforcements at the different values of the fixed-interval schedule. The degree of curvature was measured by the Index of Curvature (Fry, Kelleher, and Cook, 1960), which has a value of 0.0 when the rate is constant; overall positive acceleration is indicated by positive values having a maximum of +1.0.

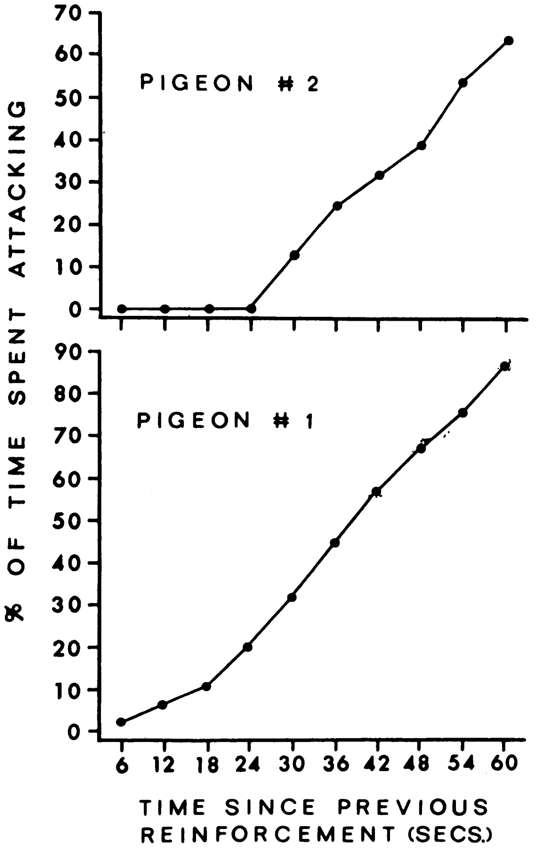

Fig. 3. Percentage of the session duration that pigeons attacked during the interval between reinforcements for the 1-min fixed-interval schedule of reinforcement. The percentages are not cumulative over the preceding class intervals and encompass only a single 6-sec interval. Food reinforcement occurred at the very beginning and very end of the curves.

Gollub (1964) has found that this statistic is closely correlated with other measures of curvature of fixed-interval responding. For both pigeons, the degree of positive curvature was an inverse function of the duration of the fixed-interval. Attack showed a high degree of positive curvature during the shorter fixed-interval values but became more uniform as the values increased. Almost no curvature occurred at the 20-min fixed-interval schedule for either pigeon.

The cumulative response records of Fig. 5 show the moment-to-moment occurrence of attack during the 2-min fixed-interval schedule of reinforcement. Some positive acceleration of attack was evident after all of the food reinforcements but considerable variability exists within individual intervals, as for example in the last interval in the curve for Pigeon #2. This degree of variability seems to exceed that found by Ferster and Skinner (1957, Fig. 128, 150) for the key-pecking response of pigeons.

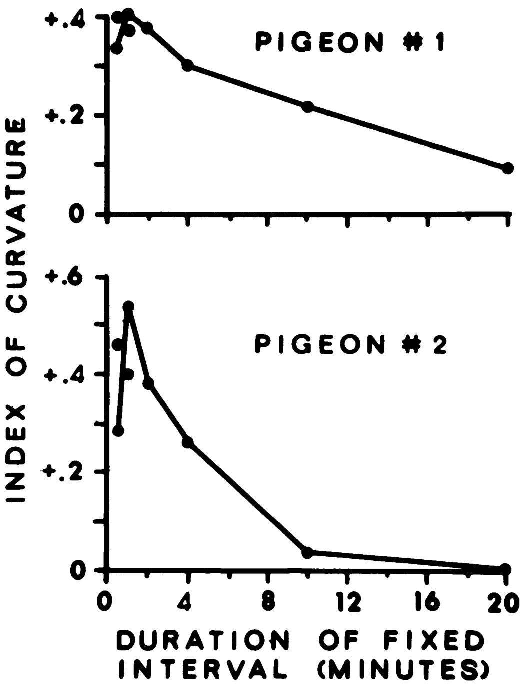

Fig. 4. Attack by Pigeons #1 and #2 against a target pigeon during the interval between reinforcements during fixed-interval reinforcement of the attack. The manner in which attack was distributed within the interval is reflected by the Index of Curvature, positive values of which show positive acceleration. Each data point is based on the last five sessions of exposure to the designated fixed-interval schedule; the 60-min interval is not shown because of the large variability of the Index at that time. The points unconnected by the line are redeterminations.

The continuous records of Fig. 5 show little intrasession change. Except for a reduced duration of attack during the first 2-min interval (warmup effect), attack duration remained fairly uniform throughout the session. Table 2 shows that attack did not systematically increase or decrease during the session. One pigeon showed a slight increase of attack during the session at the longer fixed-interval durations, the other a slight decrease. The data for the 60-min fixed-interval schedule are not included because of the intrasession variability caused by the small number of reinforcements per session.

Table 2

The mean duration of attacks during each half of the session expressed as a percentage of the duration of attack in the entire session.

	Pigeon #1		*Pigeon #2*	
Fixed-Interval Duration	*1st Half of Session*	*2nd Half of Session*	*1st Half of Session*	*2nd Half of Session*
0.5 min	51	49	52	48
1.0 min	51	49	50	50
2.0 min	48	52	49	51
4.0 min	53	47	56	44
10.0 min	44	56	57	43
20.0 min	40	60	60	40

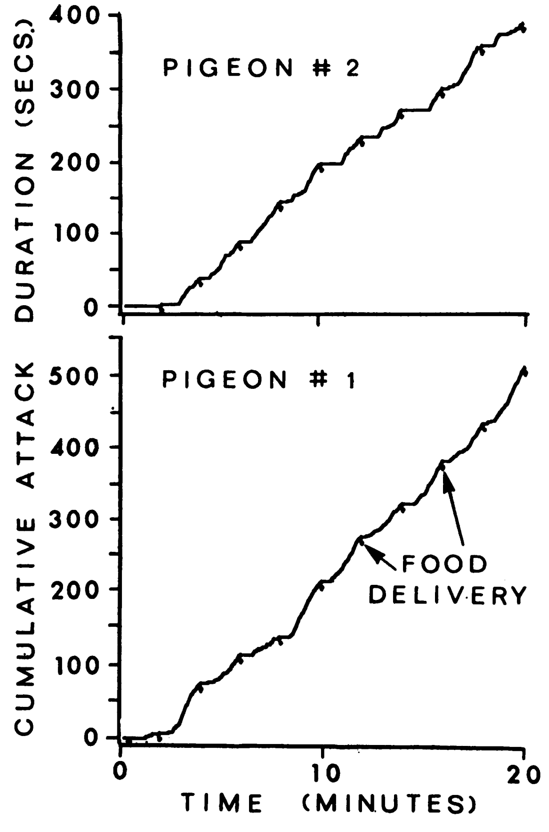

Fig. 5. Sample records of cumulative attack duration of pigeons attacking a target pigeon during a 2-min fixed-interval schedule of reinforcement of attacks. Delivery of a food reinforcement is indicated by the small downward markings, two of which are indicated by the arrows. The start of the records corresponds to the start of a session. The recordings were from a Gerbrands cumulative response recorder, the pen of which moved up one step for every 1.0 sec of attack. Attack was measured from the output of a switch attached to the enclosure in which the target pigeon was restrained.

DISCUSSION

The present results provided quantitative evidence and support for the observations of Reynolds *et al.* (1963) that pigeons can be conditioned to attack. The high incidence of attack during conditioning was the result of the reinforcement procedure: pigeons did not attack when food was absent, or discontinued (extinction), or delivered independently of the attack. The reinforcement procedure exerted substantial control over the aggressive behavior. During reinforcement, the pigeons attacked throughout each session and for as many sessions as the procedure was used. These results should not be interpreted to mean that the pigeon was transformed from a peaceful animal to an aggressive one. The absence of attack during extinction demonstrates that the "temperament" of the pigeon was of little relevance except insofar as the temperamental state is considered a product of the reinforcement contingencies.

In a previous study, the abrupt transition from continuous reinforcement to extinction caused pigeons to attack (Azrin *et al.*, 1966). This elicited attack was absent in the present procedure, probably because the transition from reinforcement to extinction was gradual and because extinction was conducted when reinforcements were very infrequent (1 hr apart). Taken together, the results show that schedules of food reinforcement can produce attack either by elicitation or by direct operant reinforcement.

When the key-pecking response of pigeons is reinforced by food, the response rate has been greatest at the start of the session, and decreasing thereafter (Ferster and Skinner, 1957, Chapter 5). The attack responses in the present study were not more frequent at the start of the session, perhaps because of the counteraggression of the target bird upon being attacked; punishment has been found to decrease responding more at the start of a session (Azrin, 1959, 1960). Figure 5 showed examples of this warmup effect at the start of the session similar to the warmup (Azrin and Holz, 1961) produced by shock punishment during fixed-interval reinforcement of key-pecks. If this explanation is correct, it appears useful to consider attack as a response with an inherent punishment contingency attached.

The proportion of time spent in attack was a direct function of the frequency of reinforcement, as has been found previously for the rate of bar-pressing responses during fixed-interval food reinforcement (Skinner, 1938, Fig. 29; Wilson, 1954). Similarly, the temporal patterning of attack was determined by the fixed-interval reinforcement schedule: during the period immediately after reinforcement, the birds almost never attacked, whereas they were engaged in fairly continuous attack before each reinforcement. Attack accelerated positively between reinforcements. This effect is similar to the positive acceleration of responses obtained during fixed-interval reinforcement of arbitrary responses such as bar-pressing by rats (Skinner, 1938; Mechner, Guevrekian, and Mechner, 1963), key-pecking by pigeons (Ferster and Skinner, 1957; Azrin and Holz, 1961; Holz and Azrin, 1962), and observing responses by humans (Holland, 1957; Azrin, 1958).

Positive acceleration of responses between reinforcements is generally considered to be a distinctive characteristic of fixed-interval schedules of reinforcement. The basis for this generalization is extensive. Positive acceleration has characteristically resulted when the fixed-interval duration is as long as several hours (Ferster and Skinner, 1957; Dews, 1965) and when the reinforcing events are as diverse as food (Skinner, 1938), water (Charney and Reynolds, 1965), intracranial stimulation (Pliskoff, Wright, and Hawkins, 1965), avoidance of punishment (Azrin, Hake, Holz, and Hutchinson, 1965) and detection of targets (Holland, 1957; Azrin, 1958). The present results were somewhat unexpected, therefore, in revealing that the positive curvature decreased, as the fixed-interval duration was increased, and disappeared at the longer durations. This relationship does not seem to have been reported previously except in a study (Hanson, Campbell, and Witoslawski, 1962) of the lever-pressing responses of rats during four different values of the fixed-interval component of a chain fixed-interval fixed-ratio schedule. Visual comparison of the cumulative response records of some studies suggests that this loss of positive curvature does apply to simpler responses (see Skinner, 1938, Fig. 30 *vs* Fig. 31; Ferster and Skinner, 1957, Fig. 187, 194, 196), but comparison of the records of other studies of fixed-interval duration does not reveal a loss of curvature (*i.e.*, Pliskoff, 1965, Fig. 2; Azrin *et al.*, 1965, Fig. 6; Millenson, Hurwitz, and Nixon, 1961, Fig. 4; Segal, 1962, Fig. 2). Definitive confirmation of this loss of curvature awaits further study with responses other than attack; the destructive nature of the aggressive behavior precluded the use of very long sessions. As a consequence, fewer reinforcements were given for the longer fixed-interval values and may be partly responsible for the smaller degree of curvature at those values.

The attack behavior differed from other behavior maintained by positive reinforcement in that it was more variable and appeared to have an "intrinsic momentum", as evidenced by the failure to terminate attacks as soon as food was available. The greater variability, and seeming "persistence" of attack relative to other behaviors, appears to be caused partly by the social nature of the attack behavior, *i.e.*, movements and especially counteraggression by the target. In spite of these differences, the present findings indicate that the complex social behavior of attack resembles simpler non-social responses, in that it can be controlled over a wide range of values by the use of positive reinforcement, and the pattern of attack can be specified from a knowledge of such factors as the frequency and schedule of operant reinforcement.

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