EXTINCTION-INDUCED AGGRESSION DURING ERRORLESS DISCRIMINATION LEARNING[1]

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Pigeons were trained to discriminate without errors between a green light and a dark key. The key-pecking response was reinforced in the presence of green, and extinction was in effect in the presence of the dark key. The duration of the dark key was gradually increased during the first few sessions of conditioning. The opportunity to attack a restrained target pigeon was also present. During discrimination training, the rate of attack in the presence of the dark key was higher for each animal than the operant level, even though most of the animals acquired the discrimination without errors. Furthermore, the rate of attack did not decrease during 45 sessions of discrimination training. Attack also occurred in the presence of the green stimulus, although to a lesser extent than during extinction. Reinforcement during green is a determinant of attack during extinction because removal of reinforcement virtually eliminated attack during extinction.

In a successive discrimination, the subject is alternately presented two stimuli: S+, in the presence of which responses are reinforced, and S−, in the presence of which responses are not reinforced. Terrace (1963a, 1966, 1972) found that the behavior resulting from a procedure in which S− was introduced gradually during the first session of conditioning, differed in several fundamental aspects from a procedure in which S− was introduced abruptly at full duration and intensity after several sessions of nondifferentially reinforced responding to S+. With the first procedure, pigeons emitted very few responses during S− (errorless learning) while the second produced many responses during S− (errorful learning). Although eventually, responses during S− disappeared, the stimuli also acquired nondiscriminative functions as by-products of the discrimination training.

These by-products have included: (1) behavioral contrast (Terrace, 1963a), in which the response rate during S+ increases when S− is introduced; (2) responding induced during S− by certain drugs (Terrace, 1963b); (3) the peak shift (Terrace, 1964), in which fol-

lowing discrimination between two stimuli on the same dimension, the maximum or peak of the generalization gradient occurs at a test stimulus that is displaced from S+ in a direction away from S−; (4) inhibitory stimulus control (Terrace, 1972), in which, following discrimination training between two stimuli on different dimensions, an inhibitory or incremental gradient is obtained with a minimum at S−; (5) responses to an escape key that removes S− (Rilling, Askew, Ahlskog, and Kramer, 1969); and, (6) aggression during S− against a restrained target pigeon (Azrin, Hutchinson, and Hake, 1966). In several extensive reviews of these by-products, Terrace (1966, 1972) argued that they are obtained only after discrimination learning with errors and do not occur when an errorless procedure is employed. Another characteristic of these by-products of discrimination learning mentioned by Terrace (1972) is their gradual disappearance with extended training.

Terrace (1971) compared the amount of escape from S− when S− was gradually introduced during the first session of conditioning with the escape behavior obtained when S− was introduced abruptly after 21 sessions of nondifferentially reinforced responding to S+. Escape from S− was not obtained for the first group, which learned the discrimination without errors, but a substantial number of escape responses were obtained from the second group, which learned the discrimination with

errors. This led Terrace to conclude that ". . . the occurrence of non-reinforced responding to S— is the crucial factor in rendering S— aversive (P. 160)."

However, errors during S— may not be the only factor responsible for the by-products of discrimination learning. Rilling, Richards, and Kramer (1973) demonstrated that the occurrence of non-reinforced responding to S— is not the crucial factor contributing to the aversiveness of S—. Following Terrace (1963a), four different groups of pigeons were employed that differed in the time and manner in which S— was introduced and also differed with respect to errors. The pigeons could terminate S— by producing a timeout period. In general, groups that differed with respect to errors did not differ with respect to the number of timeouts produced: the correlation between errors and timeouts for the four groups was +0.06. Escape from S— was more likely when S— was introduced late in training. For example, escape from S— was obtained from an errorless bird after S— was introduced gradually following several sessions of nondifferentially reinforced responding to S+, but few escape responses were obtained from errorless birds when S— was introduced gradually during the first session of discrimination training. An interpretation of these data is that the procedure for introducing S—, rather than the number of errors obtained during S—, is a major factor determining the aversive of S—.

An errorless procedure for introducing S— was used in the present experiment to determine if a second by-product of discrimination learning is unrelated to the number of responses to S—. The procedure developed by Azrin et al. (1966) of aggression against a target pigeon was employed. In their procedure, brief periods of continuous reinforcement alternated with 5 min of extinction. In addition to the experimental pigeon, a second partially restrained target pigeon was present in the experimental chamber. The duration of attack against the target pigeon was a direct function of the number of reinforcements and an inverse function of time since termination of reinforcement. With a high degree of consistency, Azrin et al. results showed that attack occurs at the moment of transition from continuous reinforcement to extinction, which led them to conclude that the interruption of eating is an aversive event.

To obtain errorless learning in the present experiment, stimuli that are easily discriminated by pigeons were employed, with S+, a green key correlated with a variable-interval 30-sec schedule of reinforcement (VI 30-sec) and S—, a dark key, correlated with extinction. In a variable-interval schedule, a response is reinforced after a variable interval of time from a previous reinforcement. An ABAB design, in which A was the presentation of S— alone without S+ and B was discrimination training, was employed as the basic procedure to determine if aggression is a characteristic by-product of discrimination training. The question of primary interest was whether the attack rate during S— increased over the baseline during discrimination training when S+ and S— were presented in alternation. In addition, the design provided 45 sessions of discrimination training during Condition B, so that it was possible to determine if aggression disappeared with extended training.

METHOD

Subjects

Seven adult, female White Carneaux pigeons, all experimentally naive, were maintained at 80% of their free-feeding weights. White Carneaux pigeons with various experimental histories and free access to food in their home cages served as target subjects. Daily pairings of target and experimental animals were unsystematic.

Apparatus

A Lehigh Valley Electronics test chamber for pigeons equipped with a model 1348 QL tricolor stimulus light was employed. The right key, which required a minimum force of about 20 g (0.2N) to operate, was used throughout the study while the left key remained covered. Additional specifications of the chamber and the procedures for restraining the target pigeon were fully described by Richards and Rilling (1972). Briefly, the target pigeon was restrained in a can at the rear of the chamber so that only its head and a portion of its breast were visible to the experimental animal. An attack was defined by a force of 100 g (0.98N), which closed a microswitch mounted underneath the can.

Procedure

The experiment was carried out in seven phases.

Phase 1. During this 10-day period, the baseline rate of attack in the presence of S− was obtained before shaping the pecking response. The key remained dark for 60-sec periods separated by a 4-sec blackout, during which all of the lights in the chamber were extinguished. During each session in Phase 1, S− was presented 50 times.

Phase 2. Following shaping, S+ had a duration of 60 sec, during which responses on the right key were reinforced on a VI 30-sec in the presence of a green light. The same VI 30-sec schedule was in effect in each phase in which S+ was presented. A dark key was correlated with extinction. Reinforcement was 3-sec access to mixed grain, during which the key was illuminated with a red light. During S+ and S−, a dim houselight on the front panel and three houselights above the target bird were illuminated. A 4-sec blackout separated S+ and S−.

In a previous experiment, Rilling, *et al.* (1973) employed an Early-Progressive procedure in which a successive discrimination between green and red was established with an average of 56.4 responses to S−. To reduce the number of responses during S− further, a dark rather than a red key was employed during S−. The five sessions immediately following shaping were devoted to increasing the duration of S− gradually to its full duration of 60 sec. At the beginning of each of these sessions, the duration of S− was reduced to 3 sec or less. The specific durations employed for S− are presented in Table 1 of Rilling, Richards, and Kramer (1973). Each session was terminated after 25 presentations of S−. The target birds were absent during this period. Phase 2 lasted five days.

Phase. 3. The target birds were reintroduced during this phase and remained throughout the experiment. During this 15-day phase, the 60-sec S+ and the 60-sec S− were alternated in a pseudo-random series in which each stimulus did not occur successively more than three times. A 4-sec blackout separated stimulus presentations. Each session consisted of 25 presentations of each stimulus. Responses in the presence of S− did not affect the occurrence of S+.

If an attack occurred during S+, the first peck on the key following the attack delayed the availability of reinforcement on the VI schedule until a subsequent response occurring at least 5 sec after the first response.

Phase 4. This phase was designed to provide a baseline rate of responding to S+ in order to assess the possible occurrence of behavioral contrast during the discrimination. During this 15-day phase, S+ was presented in alternation with itself for 25 presentations, separated by the 4-sec blackout. The dark key, S−, was not presented.

Phase 5. The birds returned to the conditions of discrimination training employed in Phase 3. Phase 5 lasted 15 days.

Phase 6. The positive stimulus was omitted and the baseline rate of attack in the presence of S− following reinforcement was again determined. The conditions were identical to Phase 1 in which S− alternated with itself. The key remained dark for 60 sec separated by the 4-sec blackout. Phase 6 was in effect for 15 days.

Phase 7. The birds were again returned to the conditions of discrimination training employed in Phase 3. Phase 7 lasted 15 days.

RESULTS

Figure 1 shows the average rate of attack for each animal during various phases of the experiment, excluding the baseline sessions of Phases 1 and 6. The data in the upper panel are the average rates of attack during S+ and the data in the lower panel are the average rates of attack during S−. The data for the birds in each section of the panel are ordered from left to right, birds one through seven, by ranking the animals from the lowest to the highest on the basis of the rate of attack during S− in Phase 3.

An errorless bird is defined by Terrace (1972) as one that makes approximately 25 errors. In Figure 1, the number above the attack rate during S− indicates the number of errors that occurred during S− in that phase of the experiment. No pecks were made on the darkened key during Phase 1, the initial baseline period before reinforcement. The procedure was effective in producing errorless learning for six of the seven animals and the seventh bird made only 36 errors. These data include errors for Phase 2 when S− was gradu-
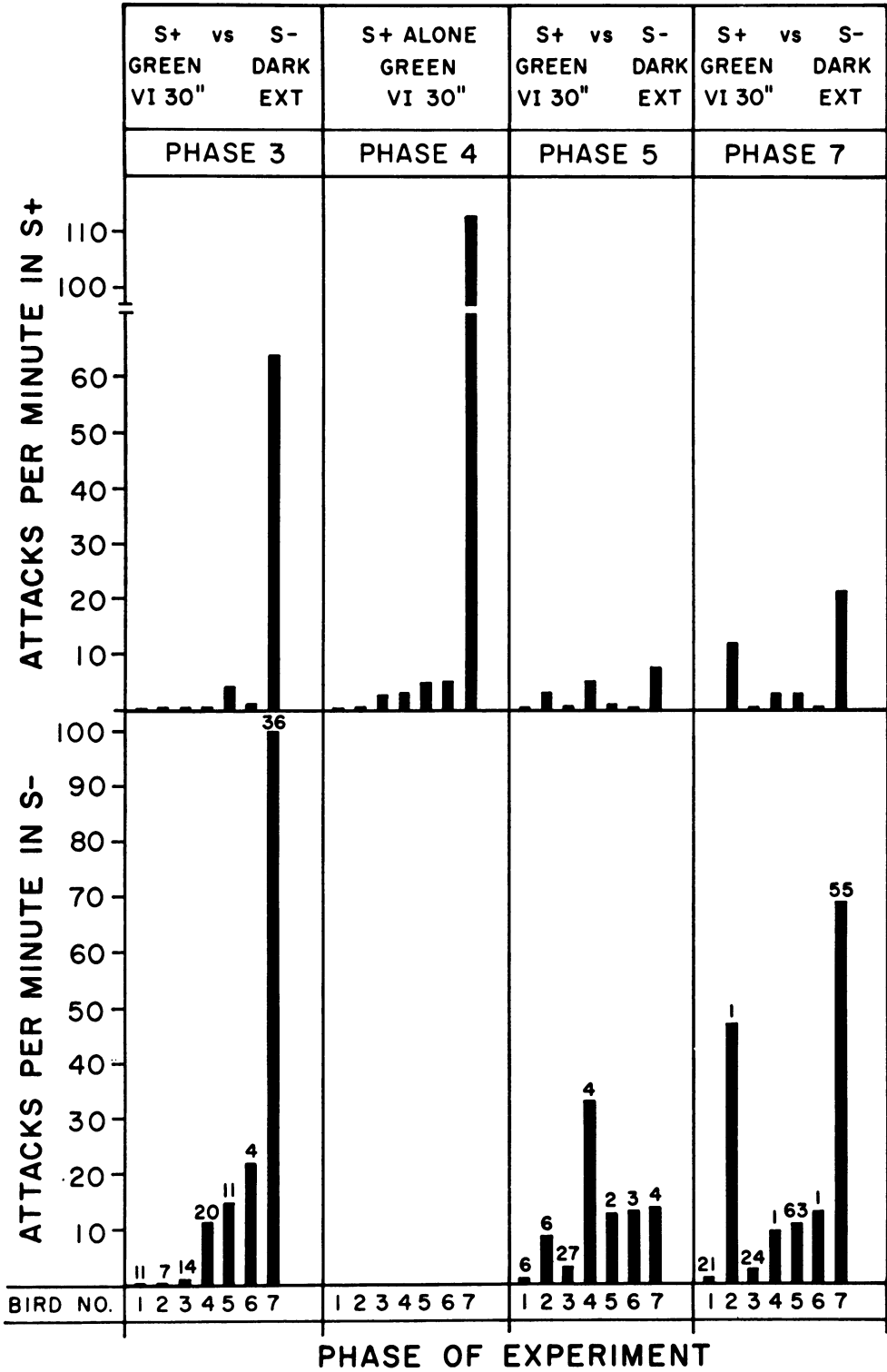
Fig. 1. (Upper panel) Rate of attack during S+ for each animal during the phases of the experiment. (Lower panel) Rate of attack during S— for each animal during the phases of the experiment. The number above each bar indicates the number of errors during that phase. The number of the bird is indicated below the bar.

ally introduced. During Phases 5 and 7 of discrimination training, a few additional errors were obtained for each bird. When S— was presented alone following discrimination training in Phase 6, two of the birds made substantial responses during S—, 514 responses for Bird 1 and 1669 responses for Bird 5, but the five remaining birds each made fewer than 15 responses during S—. Three of the seven animals, Birds 2, 4, and 6, were errorless throughout all seven phases of the experiment.

Six of the seven birds had an average attack rate of zero attacks per minute during Phase 1, while the remaining bird had an attack rate of 0.3 attacks per minute. The lower panel of Figure 1 shows that discrimination training in Phase 3 increased the rate of attack during S— for five of the seven birds over the rate that prevailed in Phase 1 when S+ was not presented. When discrimination training was resumed in Phase 5, attack during S— was observed for each of the seven birds. When S+ was omitted and S— was presented alone in Phase 6, each bird showed a drop in the attack rate during S— to an average of 0.6 attacks per minute. During the final sessions of discrimination training in Phase 7, each bird showed an increase in the rate of attack during S— as compared with the baseline rate in Phase 6. Extended discrimination training did not reduce the rate of attack during S—, since the rate of attack obtained in Phase 7 was clearly not less than the rate obtained in Phase 3. While there were large individual differences in the rates of attack during S—, attack occurred, even though many of the birds were errorless in most phases of the experiment.

The upper panel of Figure 1 shows that attack also occurred during S+ in Phases 3, 5, and 7, although at a lower rate than during S—. In Phase 4, S— was omitted and S+ was presented alone. Figure 1 shows that attack continued during S+ in the absence of S—. In fact, six of the seven birds showed an increase in attack in S+ in Phase 4 as compared with the rate of attack in Phase 3. This increase in the rate of attack during S+ precluded an analysis of behavioral contrast because the response of attack against the target bird competed with and lowered the rate of responding on the key. Therefore, data on the rates of responding during S+ were not presented.

To determine how the rate of attack during S— was distributed within the 1-min periods of

extinction, the attacks during S— for the 45 sessions of discrimination training were divided into three class intervals of 20 sec each. All 45 sessions were included in the analysis because the pattern of attacks during Phases 3, 5, and 7 was very similar. Figure 2 shows the distribution of the rate of attack during S— for each subject as a function of the amount of time that the animal had been exposed to S—. The ordering of the data for the individual birds is the same as in Figure 1. For each of the seven birds, the rate of attack was highest in the first 20 sec after S+ terminated and decreased monotonically to the lowest rate during the last 20 sec of S—.

Informal visual observation supplemented the automatic recording of attack via the closure of the microswitch beneath the target bird. The aggressive responses observed during S— were similar to the three components of the aggressive response in pigeons that were analyzed by Åkerman (1965), Brown (1970), and Fabricius and Jansson (1973). Following Phase 7, several of these aggressive responses during S— were photographed for Birds 5 and 1, which were errorless throughout the experiment. The first response is bowing, which frequently precedes attack. In bowing, following erection of the head and body the bird ruffles the feathers of the neck and bows the head towards the ground while walking in circles and emitting cooing calls. The second response, illustrated in Panel A of Figure 3 was attack intention in which, while standing upright, the bird raises the feathers of its neck and pecks in an open space in front of its opponent while vibrating its wings. The final response was attack itself. Panel B shows an
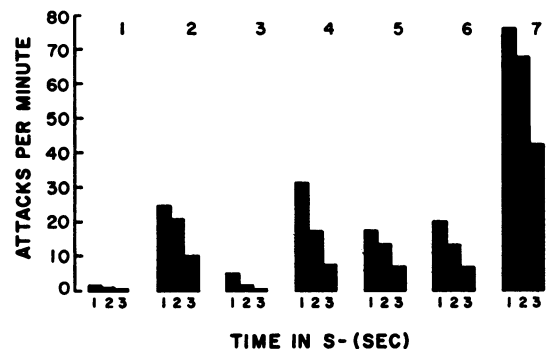

Fig. 2. Rate of attack during S— for 45 sessions of discrimination training for each subject in class intervals of 20 sec.
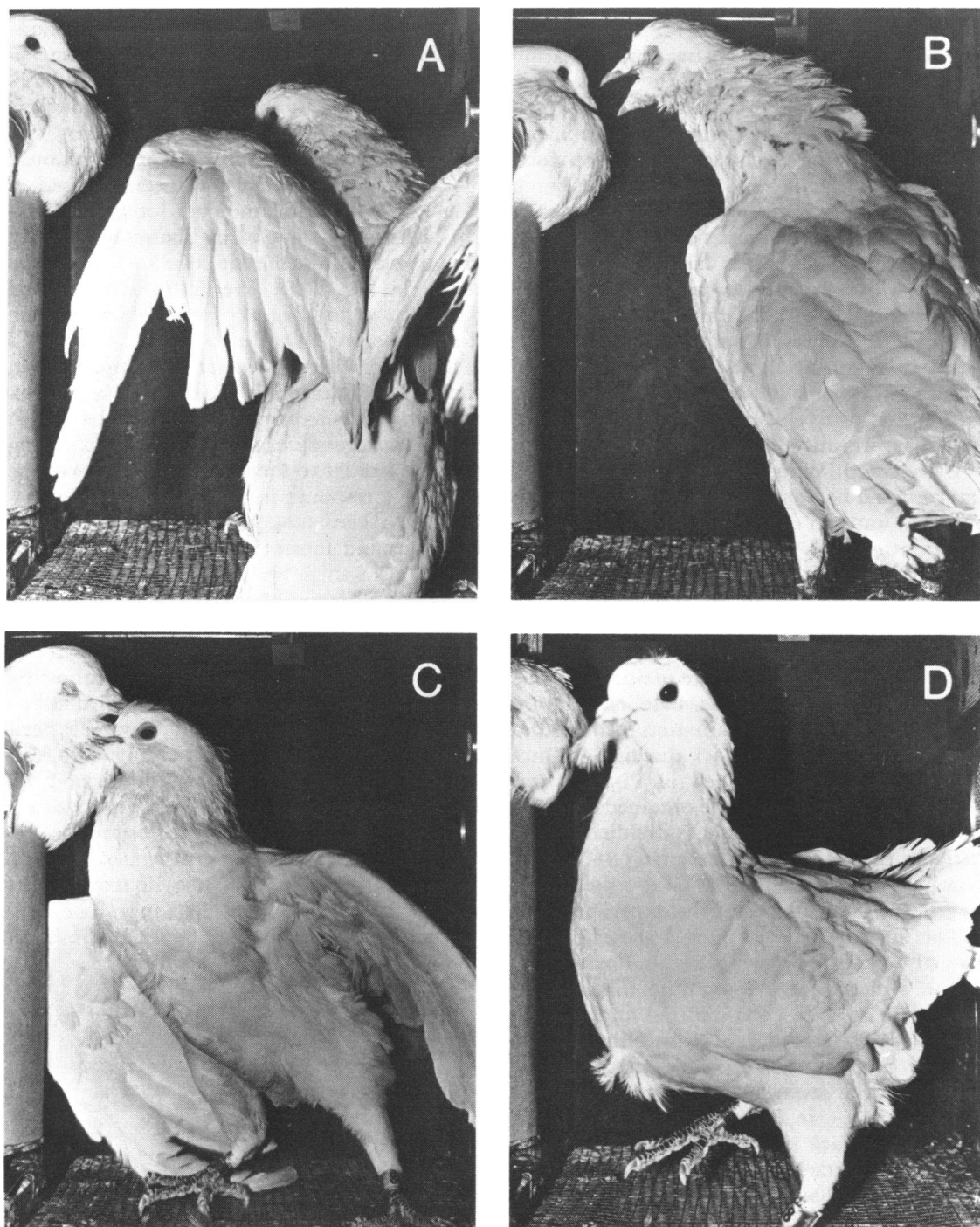
Fig. 3. Photographs of two pigeons during S— that acquired the discrimination without errors. Section A illustrates attack intention and B illustrates attack for Bird 5. Section C shows attack for Bird 1 and D shows Bird 1 shortly after an attack response.

attack response for Bird 5. Panel C shows an attack response by Bird 1. Panel D shows Bird 5 immediately after an attack terminated.

DISCUSSION

Attack during S—, and to a lesser extent during S+, was a by-product of errorless discrimination training on the *mult* VI 30-sec EXT schedule of reinforcement. According to a theory developed by Terrace (1966, 1971, 1972), behavioral by-products of discrimination training are observed only when the discrimination has been acquired with non-reinforced responding during S—. Furthermore, when a discrimination is trained without errors, none of the by-products of discrimination learning are obtained. These data demonstrate that aggression during S— is an exception to this generalization. Another presumed characteristic of a by-product of discrimination learning is its gradual disappearance with extended training. In the present experiment, the attack persisted throughout 45 sessions of discrimination training and did not decrease with this amount of extended training. Again, aggression did not function as a typical by-product of discrimination learning. Further research is needed to determine if aggression during an errorless S— is an isolated exception to Terrace's theory or whether other by-products such as behavioral contrast or inhibitory stimulus control may also be obtained under conditions of errorless learning.

The removal of S+ in Phase 6 virtually eliminated attack during S—. Similarly, Rilling et al. (1969) found that not presenting S+ reduced the number of escape responses from S—. The distribution of attacks during S—, in which the probability of attack was highest after S+ terminated, was similar to that obtained by Azrin et al. (1966) and also paralleled the distribution of escape responses from S— obtained by Rilling et al. (1969). The sensitivity of the attack and escape responses to the withdrawal of the positive condition and the distribution of these responses within S— leads to the view that positive reinforcement during S+, rather than errors during S—, is one of the factors responsible for escape and attack during S—. These results suggest that the escape and aggression-inducing properties of S— are not primarily due to the contingencies prevailing during S—, but are a contrast effect determined by the contingencies prevailing during S+.

While the results discussed above demonstrated parallel relationships between aggression and escape during S—, aggression following a procedure in which the duration of S— was gradually increased during the first few sessions of conditioning is inconsistent with results obtained by Terrace (1971) and Rilling et al. (1973). They obtained relatively few escape responses from an S— with an errorless procedure. Thousands of attacks against the target pigeon were recorded for some of the birds in this experiment, yet very similar conditions produced fewer than 100 escape responses in the same condition of the Rilling et al. (1973) experiment. Clearly, the aggression measure shows a much larger effect than the escape measure. One interpretation of these data is that S— acquires aversive properties following errorless discrimination learning and that aggression is a more sensitive index of the aversive properties of S— than the escape response. Another interpretation of the lack of correlation between escape and aggression is that two different concepts should be used, rather than the single one of aversiveness. Additional comparisons between the various measures of an aversive stimulus are necessary before a choice between these two alternatives can be made.

These data on schedule-induced aggression fit neatly into a theoretical system proposed by Falk (1971), in which schedule-induced aggression is classified as an adjunctive behavior. Adjunctive behavior is not required by a schedule of reinforcement, but the rate of the adjunctive response is increased at times when the probability of reinforcement is low. Examples of adjunctive responses are polydipsic drinking and attack in schedule-induced aggression. An important characteristic of adjunctive behaviors is that a dependency between the response and reinforcement is not critical to the generation of the adjunctive behavior. Azrin et al. (1966) obtained extinction-induced aggression when the food was presented independently of the animal's behavior. Falk (1966) obtained an inverted U function between the amount of water intake in polydipsia and the length of the fixed interval, in which the rate of water intake increases up to a maximum value and then decreases. Brown and Flory (1972) obtained a similar

inverted U function between escape from a fixed interval and the length of the fixed interval. It would be interesting to determine if adjunctive behaviors and the by-products of discrimination are each produced by the same controlling variables.

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