SCHEDULES OF ELECTRIC SHOCK PRESENTATION IN THE BEHAVIORAL CONTROL OF IMPRINTED DUCKLINGS¹

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The behavioral effects of various schedules of electric shock presentation were investigated during and after the imprinting of Peking ducklings to moving stimuli. The behavior of following a moving imprinted stimulus was differentially controlled by a multiple schedule of punishment and avoidance that respectively suppressed and maintained following behavior. Pole-pecking, reinforced by presentations of the imprinted stimulus, was suppressed by response-produced shock (punishment); various schedules of response-independent shock and delayed punishment had an overall minimal effect. The delivery of response-independent shock in the presence of one of two stimuli, both during and after imprinting, resulted in a marked reduction in choice of the stimulus paired with shock. The experiments provide no support for a differentiation of imprinting from learning on the basis of the behavioral effects of aversive stimuli. Instead, as is the case with other organisms, the schedule under which shock is delivered to imprinted ducklings appears to be an important determinant of the temporal patterning of subsequent behavior.

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The schedule under which shock is presented is an important determinant of the effects this event has on behavior (Kelleher and Morse, 1968, 1969; McKearney, 1968,

1969). Morse and Kelleher (1970), for example, reported that the delivery of electric shock can both engender and suppress responding, depending on the manner in which shock is scheduled. In the context of imprinting, shock has typically increased responding (Kovach and Hess, 1963; Moltz, Rosenblum, and Halikas, 1959), a finding that has been interpreted as distinguishing imprinting from learning (Eibl-Eibesfeldt, 1970; Hess, 1964). Those experiments reporting a shock-induced enhancement of responding, however, used only schedules of response-independent shock. Recently, it has been shown that when the following behavior of imprinted ducklings produces response-dependent shock, this response is suppressed (Barrett, Hoffman, Stratton, and Newby, 1971). These results appear to indicate that in imprinting, as in other situations, the schedule of shock delivery is of critical importance in suppressing or increasing responding.

The present research was conducted to analyze in greater detail the behavioral effects of different shock schedules presented both during and after the imprinting of newly hatched ducklings to moving stimuli. The results support the view that there is no basis for differentiating imprinting from learning on the grounds that the effects of shock on these behaviors are dissimilar.

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EXPERIMENT I: CONTROL OF FOLLOWING BY A MULTIPLE SCHEDULE OF SHOCK PRESENTATION

This experiment sought to ascertain whether the following response could be discriminatively controlled by two different stimuli in the presence of which different shock schedules occur. Although previous work has shown that following can be controlled by consequent noxious events (Barrett *et al.*, 1971), a successful systematic replication (Sidman, 1960) of that work would show that, in an individual duckling, following could be differentially controlled not only by the shock schedule but also by the stimuli in the presence of which these shocks occur.

METHOD

Subjects

Five Peking ducklings (*Anas platyrhynchos*) hatched in visual isolation in a forced-air incubator were used. The eggs were obtained from either the Wayne Duck Farm, Wayne, Ohio or from the C and R Duck Farm, Long Island, New York. Once removed from the incubator, the ducklings were housed individually in visually isolated containers with food and water continuously present. The ducklings were five to eight days old at the start of the experiment. Before this, starting within the first 24 hr after hatching, they received daily 60-min exposures to a plain white moving stimulus. The five ducklings were selected on the basis of reasonably consistent high-rate following.

Apparatus

The basic apparatus consisted of a plywood box 55 by 24 by 29 in. (140 by 61 by 74 cm) divided lengthwise into two equal compartments. An opening 48 by 12 in. (122 by 31 cm) was cut into the partition dividing the compartments and was fitted with stainless-steel screen. The rear compartment was equipped with HO-gauge track that ran the length of this portion of the apparatus. Mounted on a model train engine resting on this track was a foam rubber stimulus 9 by 4 by 4 in. (23 by 10 by 10 cm) that was either solid white or black and white cross-hatched. The speed of the moving stimulus was approximately 12 in.

(30 cm) per second. Both the rear (stimulus) compartment and the forward (subject) compartment were illuminated by separate pairs of 75-w reflector flood lamps. The lighting was such that the stimulus could be seen from the subject side only when the rear compartment was illuminated. Lighting in both compartments could be separately manipulated. A Gerbrands pigeon key, to which a vertical balsa-wood pole 0.75 by 0.75 by 12 in. (1 by 1 by 30 cm) was attached, was mounted on the subject's side of the partition dividing the two compartments. The pole extended down from above the screen, dividing it lengthwise into two equal halves. A force of 2 g or 0.02N (measured at the base) was required for operation of the pole.

When not in use, the pole was recessed into a channel that ran the height of the screen. At the base of the pole and extending vertically up its width for 2.25 in. (6 cm) was a transparent Lucite strip. Affixed behind this strip, in the hollow of the pole, were three miniature (0.3-w) bulbs that could illuminate this region of the pole with a conspicuous stimulus display.

Distress calls were detected by a microphone located outside the apparatus, 12 in. (30 cm) from the front-center of the subject compartment and positioned at the level of the duckling's head. The microphone fed into a specially designed voice-key that was maximally sensitive to frequencies between 3000-4000 Hz, the dominant frequencies of the duckling's distress calls (Collias and Joos, 1953). The voice-keys were adjusted to respond to an intensity of at least 68 dB at 3500 Hz, thereby precluding their responding to "contentment cheeps", which have frequency characteristics comparable to the distress call but are much less intense.

Shock was generated by an Applegate constant current stimulator usually set to deliver a 1-mA pulse of 0.3-sec duration. Shock was delivered to a harness worn around the duckling's wings. The harness was connected to a Scientific Prototype swivel that permitted unrestricted movement throughout all portions of the apparatus. In some cases, the harness was worn continuously and, for these subjects, consisted of wing-bands that were adjusted to fit the individual duckling. The wing-bands were connected to the swivel by lightweight alligator clips during testing.

Events were scheduled through standard relay equipment and were recorded on an Esterline Angus operations recorder, all located in an adjacent room. A closed-circuit TV system permitted continuous observation of the subject and behavioral events. A hand-operated switch was used to denote periods of following on the recorder and simultaneously to deliver shock.

Procedure

The first stage of this experiment consisted of an assessment of a baseline rate of following each stimulus. A criterion for following similar to that used by Peterson (1962) was used. Basically, the duckling was considered to be following when within about 8 in. (20.3 cm) of the moving stimulus and locomoting in its direction of movement. In the first session there were two alternating presentations of each stimulus. During these stimulus presentations, the amount of time spent following was recorded for baseline purposes. This period was the first occasion in which the cross-hatched stimulus was presented. Presentations of each stimulus during the baseline period and thereafter were 1 min in duration and were separated by a 20-sec period during which the rear compartment was darkened and the subject compartment illuminated. After obtaining baseline data, the different shock schedules were imposed. In the presence of one of these stimuli, shock delivery was dependent on following (punishment). During the second stimulus, following prevented shock (avoidance). The occurrence of following during the punishment component produced shock that continued to recur at 2-sec intervals until either following terminated or the stimulus was withdrawn. During the avoidance component, the failure to follow resulted in shock delivery every 2 sec until following was initiated or the stimulus was withdrawn. This procedure is essentially a multiple schedule (Ferster and Skinner, 1957) in which each of two different reinforcement schedules is associated with different exteroceptive stimuli. The two stimuli were presented randomly and there were 10 presentations of each stimulus in each session (during the early phases of training, L-4 received 20 presentations of each stimulus per session). Two sessions were conducted each day at 4 to 6 hr intervals. Ducklings B-3 and J-5 had as the original discrim-

ination the plain stimulus correlated with the avoidance schedule and the cross-hatched stimulus with the punishment schedule. For ducklings L-4, 0-6, and 0-9, the stimuli and schedules were the opposite. This was done mostly to balance the assignment of shock schedules to the two stimuli on the basis of the possibility that the original stimulus to which the birds were exposed may have interacted with one of the two schedules.

After behavior under the original discrimination stabilized, the schedules and stimuli were reversed so that the stimulus associated with the punishment of following now became the stimulus in which following avoided shock. The former avoidance stimulus was then that component of the schedule in which following was punished. A second reversal occurred when behavior again stabilized and, finally, each stimulus was presented a total of 10 times, during which no shock occurred (extinction).

RESULTS

The amount of time each duckling followed during each 1-min stimulus presentation is depicted in Figure 1. Base rates of following are indicated on the extreme left by the first two points unconnected to the remaining portion of each figure. The avoidance and punishment components of the schedule are separately labelled. For all ducklings, there was a systematic and usually rapid cessation of following during the presence of the stimulus in which following was punished. During the avoidance component, where following prevented shock delivery, this response usually remained at its initial high and fairly stable level throughout the original discrimination. Duckling L-4 required a longer time to achieve stability under the punishment schedule but rapidly did so after shock frequency was increased to one per second at the point depicted by the arrow in the figure. Transitions in following during the consecutive reversals were in accord with the change in schedules and were generally accomplished fairly rapidly, with the second reversal taking slightly longer than the first for four of the five subjects.

Behavior during extinction was variable for individual ducklings. For certain ducklings (B-3 and 0-9), behavior remained generally in accord with the schedule existing immediately before onset of extinction; following typically

Fig. 1. Amount of time following under multiple punishment-avoidance schedules, two reversals of these components, and extinction.

remained low during the punishment stimulus with a gradual decrease in following during the avoidance component. Subject 0-6 rapidly ceased following at the beginning of extinction. It would appear that most of this subject's following during the avoidance stimulus was shock-induced. A similar pattern in extinction, although somewhat more variable, is represented by J-5. Duckling L-4 maintained a high rate of following during the previous avoidance component and showed a gradual systematic increase in following during the presence of the former punishment stimulus. This appears to be consistent with L-4's behavior during training; cessation of responding during the punishment component required longer to stabilize than did consistent following during the avoidance stimulus.

Finally, there was no indication that the original selection of stimuli as either punishment or avoidance components of the schedule bore any relation to the fact that all animals were initially exposed to only the plain stimulus. Baseline rates of following were, for the most part, identical in the presence of both stimuli. Only 0-6 was an exception to this with an initially lower base rate of following the cross-hatched stimulus. This rate rapidly changed when shock was introduced.

DISCUSSION

These results are in basic agreement with those of earlier work (Barrett *et al.*, 1971), which indicated that following in imprinted ducklings is differentially sensitive to changes in schedules of aversive stimuli. The present data also indicate that the behavior of following a moving stimulus can be discriminatively controlled when aversive stimuli are used in different components of a multiple schedule. Ducklings in this experiment discriminated an avoidance schedule, during which the failure to follow resulted in the delivery of shock, from a punishment schedule in which following initiated response-dependent shock. In the presence of the punishment stimulus, following was near zero, whereas during the avoidance component, following approached near maximal rates. Similar findings, using monkeys as subjects, have been reported by Appel (1960) in which a multiple schedule of punishment and avoidance was used to develop discriminative control of responding. Appel also studied the effects of discrimination re-

versal and extinction and reported results that parallel those found in the present study.

In view of the fact that previous work (Barrett *et al.*, 1971) has shown that following can be enhanced by response-independent shock, it seems reasonable to question whether the avoidance contingency in the present experiment was more effective in producing stable following than would have been the case if response-independent shock was used. Although this cannot be answered by the present research, a comparison of the effects of response-independent shock with an avoidance contingency would be of interest in extending an analysis of the sensitivity of the duckling's following behavior to these contingencies. Presumably, however, the present avoidance schedule would elevate responding more than a schedule of response-independent shock.

In general, the present data provide further support for the view that following is sensitive to and regulated by consequent environmental events (Barrett *et al.*, 1971; Hoffman, Stratton, and Newby, 1969; Peterson, 1962; Skinner, 1966). The regularities of following under the schedules of punishment and avoidance indicate, in addition, that an imprinted stimulus can serve as a discriminative stimulus in the control of the occurrence or nonoccurrence of following. The behavior of imprinted ducklings is not uniformly enhanced by aversive stimulation and, under the present schedules, appears remarkably similar to the behavior of other organisms under comparable schedules.

EXPERIMENT II SCHEDULES OF SHOCK IN THE CONTROL OF POLE PECKING: (A) RESPONSE-DEPENDENT AND RESPONSE-INDEPENDENT SHOCK AND (B) DELAYED SHOCK

This experiment was performed to extend the analysis of shock schedules to pole pecking which, as opposed to following, requires deliberate shaping by presentations of the imprinted stimulus. As was the case with following, elevations in the rate of pole pecking have been demonstrated by schedules of response-independent shock (Hoffman, Searle, Toffey, and Kozma, 1966). The present experiment was conducted to assess the effect of punishment, various schedules of response-independent shocks, and delayed punishment on pole

pecking. Due to the explicit history of conditioning required to generate pole pecking, a comparative analysis of the effects of aversive schedules on this response and following was of particular interest.

METHOD

Subjects

Six Peking ducklings hatched and maintained in visual isolation were used. Food and water were freely available in the home cages.

Apparatus

The apparatus was identical to that used in the previous experiment. The pole, located in the center of the screen in the subject's compartment, was dimly illuminated at the base and extended out from the screen about 2 mm. Shock intensity was 1 to 1.5 mA. Sequencing of events was scheduled with relay equipment and data were collected on a Gerbrands cumulative recorder and an Esterline Angus operations recorder.

Procedure

All subjects were initially exposed to a plain white stimulus during the first 24 hr after hatching. This initial imprinting session and three subsequent similar sessions (two per day) lasted about 30 min. On Day 3, pole pecking was conditioned by presentations of the imprinted stimulus and ducklings were given two separate 30-min sessions in which each peck produced the stimulus on a fixed-ratio one (FR 1) schedule. Throughout all phases of the experiment, pecking was maintained by an FR 1 schedule of 10-sec stimulus presentation. Day 4 was identical to the previous day except that the ducklings were adapted to the shock harness while responding. The fifth day consisted of three separate 15-min sessions spaced approximately 3 to 4 hr apart, during which baseline data were obtained. The animal was simply placed in the apparatus and permitted to respond on the FR 1 schedule for 15 min. Over the next three days, all subjects received three different schedules of shock, one schedule per day, with each 15-min session again 3 to 4 hr apart. The order of exposure to these different schedules of shock delivery was balanced insofar as possible and consisted of the following schedules: response-independent shock delivered every 2 min (FT 2-min), response-independent shock delivered

on the average of every 20 sec (VT 20-sec), and punishment, where every response produced shock. In addition, all ducklings received three final sessions of response-independent shock delivered on the average of every 10 sec (VT 10-sec). Three of these subjects were exposed again to three sessions of baseline (FR 1) and were then exposed to sessions of both punishment and delayed punishment. The order of exposure to these schedules was counterbalanced. During delayed punishment, shock occurred at stimulus offset, that is, 10 sec after the onset of the stimulus and coincident with the withdrawal of the imprinted stimulus. Each schedule was in effect for three sessions and 3 to 4 hr intervened between each session. In all cases, the first 5 min of each shock session throughout the experiment consisted of a period of no shock. Thus, the ducklings had a 5-min period to establish a baseline of reinforced responding before shock was introduced which, within a given session, was in effect for a total of 10 min.

RESULTS

The number of responses per minute was obtained for all subjects individually for each of the conditions. A mean of the three sessions under each of the baseline and separate shock conditions was calculated. The resultant data, plotted as a function of time, are presented for each duckling in Figure 2. The order of shock schedules follows that depicted for each subject. The shaded areas represent the 5-min period preceding each condition during which no shock occurred. In general, these data reveal a uniform pattern of marked and rapid suppression of responding when the punishment contingency was in effect and either a maintenance or slight elevation under most of the response-independent conditions. There are exceptions to this, however, most notably Subject K-1 whose behavior under FT 2-min shock was suppressed. Subject K-7 also revealed a slight suppression of pole pecking under VT 20-sec shock. In both cases, punishment was the first schedule experienced by these ducklings. It should be noted that for both K-1 and K-7, the first shock delivered during the response-independent condition completely suppressed responding. For K-1, little recovery occurred throughout the three sessions of FT 2-min shock, whereas K-7 had a rate only slightly below the earlier baseline performance

Fig. 2. Average number of pole-pecking responses for individual ducklings under each of the baseline and shock schedules. Shaded portions represent the initial 5 min of each session during which no shocks were delivered. The order of exposure to the different schedules was identical to that depicted for each duckling. With the exception of punishment, all shock schedules were response-independent.

on the final session of VT 20-sec shock. In both cases, further exposure to response-independent shock overrode this initially suppressive effect, resulting in stable responding throughout the remaining conditions. K-3 and K-5 also showed some suppression under VT 10-sec and VT 20-sec shock respectively. Although this suppression occurred when punishment was not the first schedule to which the birds were exposed, the rate was not as low as that during punishment. For the most part, the results are unequivocal: response-dependent shock suppressed pole pecking and response-independent shock, delivered at vary-

ing frequencies, only occasionally reduced responding.

Figure 3 presents cumulative records from the final session under each of the conditions for four of the ducklings. The cumulative recorder stopped during presentations of the imprinted stimulus. Diagonal strokes denote shock delivery and the event pen signifies the occurrence of distress vocalizations. These curves supplement those of Figure 2 and illustrate the orderliness of the duckling's behavior under the various schedules. Of particular interest is the continuation of distress calls for J-2 during stimulus absence when pole peck-

Fig. 3. Cumulative records from the final session of pole pecking under the various shock schedules and baseline condition. Ordinate: cumulative responses; abscissa: time. Diagonal strokes on the cumulative record indicate deliveries of electric shock. The event pen indicates distress vocalizations. The cumulative recorder stopped during presentations of the imprinted stimulus. All shock schedules except punishment were response-independent.

ing was punished. This duckling, as did others during punishment, would make fractional approaches toward the pole and would then retreat to a far corner and begin distress calling. During response-independent shock, most distress calls were shock-induced. Otherwise, distress calls appeared early in the session before responding was initiated (e.g., K-7 under VT 20- and VT 10-sec shock). Also shown in this figure is the pronounced suppression of K-1 under FT 2-min shock after initial exposure to the punishment schedule. A characteristic of all ducklings is the continuation of reasonably high-rate responding under the final condition of VT 10-sec shock.

Figure 4 presents the data from those subjects that received 10-sec delayed shock and punishment. The data are depicted in the order in which the schedules were presented. Once again, punishment clearly suppressed responding, whereas delayed shock had little effect. Both K-5 and K-7 showed a slight recovery under punishment late in the session.

DISCUSSION

These data clearly indicate that the pole pecking of imprinted ducklings, like following, can be differentially controlled by consequent noxious events. The effects of the various schedules of shock resemble those reported for other organisms under similar schedules (e.g., Rachlin and Herrnstein, 1969).

Perhaps the most impressive evidence of the importance of the schedule of shock presentation is that under delayed shock, where shock delivery occurred at stimulus offset rather than simultaneous with its appearance, the rate of responding either remained unchanged or was slightly increased. Correspondingly, these data also indicate that the imprinted stimulus is a potent reinforcer for the imprinted duckling.

The first two experiments lead to the conclusion that the behavior of imprinted ducklings can be suppressed by aversive stimulation when appropriate schedules are specified. The introduction of shock into a pattern of ongoing behavior has multiple effects that appear to depend critically on the manner in which shock is delivered. As such, shock appears to encompass a range of behavioral effects that can be understood most readily by an analysis of the temporal relations of the

aversive stimulus to specific instances of ongoing behavior.

EXPERIMENT III EFFECTS OF RESPONSE-INDEPENDENT SHOCK ON CHOICE (A) AFTER IMPRINTING AND (B) DURING IMPRINTING

The final experiment extended the analysis of schedules of shock presentation to that of choice or preference behavior. Previous research indicates that, in pigeons, preferential responding to one of two stimuli depends on factors such as the relative density of reinforcement and the aversiveness of the schedules arranged in the presence of these stimuli (e.g., Fantino, 1969; Rachlin and Herrnstein, 1969). In imprinting research, the choice or preference test has been widely used to assess the effects of various procedural manipulations. In most cases, this has consisted of exposing a newly hatched bird to a single moving stimulus and then, at some later date, simultaneously presenting both the original and a novel stimulus. The probability of responding to either object or the amount of time spent in the presence of each usually constitutes the measure of preference or choice. A frequent finding of this procedure has been that a bird will choose that object to which it was initially exposed (Bateson, 1969). The present study examined the effects of aversive stimuli on this choice behavior. Of primary interest was whether the initial choice of an imprinted duckling could be modified by pairing response-independent shock with one of two successively presented moving stimuli. The first phase of the study followed the standard procedure of initially exposing ducklings to a single stimulus and then giving a choice test with both the old and a new stimulus simultaneously present. After this, both stimuli were repeatedly presented singly and, in the presence of one of these stimuli, the duckling received a series of response-independent shocks. No shock occurred when the second stimulus was presented. A choice test administered at the end of this procedure enabled an assessment of the effect of delivering shock in the presence of one of the stimuli.

A second aspect of this study consisted of pairing shock with one stimulus from the duckling's initial exposure to the moving stim-

Fig. 4. Pole-pecking responses during baseline, delayed punishment, and punishment. During delayed punishment, shock occurred 10 sec after response-produced presentations of the imprinted stimulus and was simultaneous with the offset of the stimulus. Each function is based on the mean of the three sessions. Shaded areas represent the initial 5 min during which no shocks were presented.

ulus in the first imprinting session (*e.g.*, before the duckling was 24 hr old) and, again, after a series of such shocks, administering a choice test. Based upon the finding that shock delivered during imprinting generally increased following in birds that were less than 24 hr old, Kovach and Hess (1963) and Hess (1964) concluded that the enhancing effect of shock is indicative of and produces more effective imprinting. If it is uniformly the case that aversive stimuli result in better imprinting, it would be expected that, in the present study, animals receiving shock to one of two stimuli during imprinting should subsequently choose that stimulus initially paired with shock. On the other hand, an analysis based upon conditioning principles would tentatively assume, as did Hess, that an animal would avoid that stimulus associated with shock when it is presented simultaneously with the non-shock stimulus.

METHOD

Subjects

A total of 14 Peking ducklings, hatched in visual isolation in forced-air incubators, were used. Once removed from the incubator, the ducklings were housed individually in visually isolated containers with food and water continuously present.

Apparatus

The apparatus was identical in all respects to that in Experiments I and II. The pole was recessed and darkened. Shock was 1 mA.

Procedure

The first phase consisted of exposing six newly hatched ducklings to a single stimulus. At the time of first exposure, the ducklings were 14 to 22 hr old. Three ducklings were exposed to the plain white stimulus and three to a black and white cross-hatched stimulus. Beginning within the age periods specified above, each duckling was placed in the apparatus with the rear compartment illuminated and the stimulus moving back and forth. There were two 30-min sessions of such exposure for three days. During the final two sessions of exposure, the duckling was habituated to the shock harness, which was simply worn around the wings while the stimulus was present and moving back and forth. On Day 4, each subject was placed in the apparatus with the rear

compartment darkened. A series of choice tests was administered that consisted of illuminating the rear compartment and presenting both the original and a novel stimulus. For those subjects exposed to the plain stimulus, the novel stimulus was cross-hatched, and for those ducklings initially exposed to the cross-hatched stimulus, the plain stimulus constituted the novel or different stimulus. During the choice tests, each stimulus was moving on one-half of the track on each side of the apparatus (divided by the position of the withdrawn pole) and the amount of time the duckling spent in each half of the apparatus was monitored and recorded. The stimuli were presented for 60 sec at the end of which both the lighting and movement of the stimuli were terminated for 20 sec. The stimuli were then presented again and this cyclical procedure continued for 10 such presentations of the stimuli. After the fifth presentation, the positions of the stimuli were reversed to counteract possible preferential responding to position alone. This sequence of choice tests provided a measure of the amount of time each duckling spent in the presence of the respective stimuli and constituted the pre-shock assessment of choice.

Approximately 2 hr later, each duckling was returned to the apparatus where these same stimuli were individually and successively presented and withdrawn on the same schedule of 60-sec presence and 20-sec absence. During each presentation of one of the stimuli, four of the ducklings received five shocks at the rate of one shock every 10 sec. Two subjects (A-7 and A-10) were shocked in the presence of the original stimulus and two (A-3 and A-14) received similar response-independent shocks in the presence of the different stimulus. B-1 and B-2 received no shock, but to assess the stability of initial choice over an equivalent amount of time, otherwise experienced the same sequence of events. Within each pair of ducklings, one subject was initially exposed to the plain stimulus and one to the cross-hatched stimulus. During the shock sessions there were 10 presentations of the stimuli, with each stimulus appearing five times in a given session. The order in which the stimuli were presented was randomly determined within and between sessions. A total of five sessions were conducted with two sessions per day on Days 4 and 5 and a final session on Day 6.

The daily sessions were spaced about 2 hr apart. Following this sequence of shock deliveries, a series of post-shock choice tests was given, the first approximately 2 hr after the final shock session and the second on the following day. Each choice test, as before, consisted of 10 simultaneous presentations of the two stimuli.

The second phase of this study consisted of initiating shock delivery during the duckling's initial exposure to the moving stimuli. There were no initial choice tests. Instead, ducklings at approximately 18 to 20 hr of age were placed in the apparatus and given successive presentations of both stimuli, with shock occurring in the presence of one stimulus in an identical manner to that specified for the previous ducklings. To control for initial stimulus presentation and shock delivery, Subjects N-3 and O-1 were shocked during the presentation of the first stimulus; for Subjects O-2 and O-4, shock occurred in the presence of the stimulus presented second. For N-3 and O-4, the shock stimulus was the cross-hatched and for O-1 and O-2, shock was delivered during the presence of the plain stimulus. Subjects N-2, N-4, Q-1, and Q-2 received no shock, but experienced the same sequence of events. As before, there were five sessions of shock followed by a series of choice tests in which both stimuli were presented. For those ducklings receiving shock, the first two sessions occurred within 24 hr of hatching. After the shock sessions, three separate choice tests were given, one 2 hr after the final shock session and the remaining two on the following day.

RESULTS

The pre- and post-shock choice data, consisting of the amount of time each duckling spent in the presence of the respective stimuli during the choice tests, are presented in Figure 5. This figure represents only those four ducklings initially imprinted to a single stimulus before delivery of shock and the no-shock controls. The pre- and post-shock histograms are based respectively on the 10 and 20 separate choice tests and represent the total time spent in the presence of each stimulus during these tests. The post-shock data were divided in half to make them comparable to the pre-shock data. The pre-shock choice tests indicate that, with the exception of B-2, each stimulus was chosen nearly equally often. After a series of

shocks, however, there was a uniform and substantial reduction in the amount of time the duckling spent in the presence of the stimulus correlated with shock. Furthermore, animals shocked in the presence of the original stimulus (A-7 and A-10) did not differ markedly from those shocked in the presence of the novel or different stimulus (A-3 and A-14). The ducklings that received no shock throughout the experiment (B-1 and B-2) essentially maintained their initial level of choice.

The data from those ducklings initially exposed to both stimuli, one of which was paired with shock from the outset, *i.e.*, from the first exposure, are presented in Figure 6. The lower half of the figure represents the four ducklings that received shock and the upper half the no-shock controls. The histograms represent the total time spent in the presence of the stimuli during the choice tests divided by three to make the data comparable with those in Figure 5. Once again, all animals spent markedly less time in the presence of the stimulus paired with shock compared to the control subjects that received no shock. These latter subjects spent nearly an equivalent amount of time in the presence of both stimuli.

In addition to the choice measures, the amount of time distress calling that occurred during the presentation of both the shock and non-shock stimuli was calculated. The data of primary interest consist of the effectiveness of both stimuli in suppressing distress vocalizations. As an additional measure of behavioral control, this analysis was performed to determine whether behavior other than choice was differentially controlled by the two stimuli. Therefore, the number of seconds of distress calling 10 sec before the onset of each stimulus (Pre-stimulus period) was compared with that which occurred during the first 10 sec after the onset of the stimulus (Stimulus period). The restriction of the Stimulus period measures to 10 sec obviated the inclusion of any shock-induced distress calls that may have occurred during the presentation of the stimulus paired with shock. The results of this analysis for ducklings shocked after and during imprinting are presented respectively in Figures 7 and 8. The data represent the mean of the final three sessions of shock and are based on distress vocalizations occurring before and during the shock and non-shock stimuli. Although Figure 7 shows that there was a sub-

Fig. 5. Choice behavior before and after response-independent shock pairings with one of two stimuli. Ducklings were initially imprinted to one stimulus. The data show the amount of time spent in the presence of the two stimuli. Ducklings A-3 and A-14 received shock in the presence of a stimulus different from that to which they were initially imprinted. Ducklings A-7 and A-10 were shocked in the presence of the original stimulus. B-1 and B-2 received no shock.

stantial amount of variability in the amount of time distress calling, it is clear that for those animals that received shock, both stimuli were effective in suppressing distress calling. In Figure 8, the data reveal, overall, a lower rate of distress vocalizations than in the older birds. This is most pronounced for the ducklings that received shock. One duckling (O-1) showed an elevation of distress calling in the presence of the stimulus associated with shock. Distress vocalizations of the remainder of the shocked animals were about equally controlled by both stimuli.

DISCUSSION

On the basis of traditional imprinting theory, the general expectations from these studies were that shock would have a minimal effect on the choice behavior of imprinted ducklings and an enhancing effect when delivered during imprinting that would result in an increased preference for the shock-associated

stimulus. In the latter case, on the basis of previous research (Kovach and Hess, 1963), animals shocked in the presence of one stimulus should subsequently choose that stimulus rather than avoid it, due to the augmentation of imprinting by aversive stimulation. In both cases, however, these assumptions were not confirmed. Instead, the results support a more conventional learning interpretation, which suggests that pairing a stimulus with shock during and after imprinting reduces choice of that stimulus. The duckling's choice of a given stimulus is neither irreversible nor rigidly stable, a finding confirming that of other individuals (Hinde, 1962; Salzen and Meyer, 1968). It also appears that imprinting, as measured by a choice test, is not enhanced by aversive stimulation.

In spite of the reduction in choice of the stimulus paired with shock, it is important to note that, in most cases, this stimulus continued to suppress distress vocalizations and, to

Fig. 6. Choice behavior after response-independent shock in the presence of one of two stimuli during initial and subsequent exposures. The figures represent the amount of time spent in the presence of the two stimuli for ducklings that were not shocked (top) and for ducklings that received shock in the presence of one stimulus from the initial exposure (bottom).

that extent, was still capable of controlling this aspect of the duckling's behavior. Only one of the ducklings showed any indication that the shock-associated stimulus was less effective in suppressing distress calls. It is interesting to note that this duckling was among those shocked during the initial exposure when, according to Hess (1964), such procedures should maximize the occurrence of imprinting. Although all ducklings spent more time in the presence of the stimulus not paired with shock, the termination of most of the duckling's distress calling by both stimuli seems to indicate that merely pairing shock with an imprinting or imprinted stimulus may not substantially modify the potential of that stimulus to control some aspects of the animal's behavior. This is not to say that variation in either shock intensity or frequency will not reduce the potential of an imprinted stimulus for controlling such behaviors as distress calls. On the basis of the single duckling showing such a reduction in control of distress vocalization by the stimulus paired with shock, it

appears possible to develop qualitatively different degrees of aversiveness and behavioral control. In the present study, rather mild and infrequent shock was used. Whether aspects of the duckling's behavior other than choice can be modified by stronger and more frequent shocks remains to be investigated.

A final point must be made about the lack of a distinct choice or preference for the ducklings initially exposed to a single stimulus. Previous research has generally indicated that the stimulus to which a bird is initially exposed is generally chosen or preferred in a subsequent choice test (Bateson, 1966, 1969; Klopfer, 1967). In fact, the present stimuli were selected on the basis of earlier work by Klopfer (1967) that demonstrated differential responsiveness to similar white and cross-hatched stimuli after an initial exposure to only one of these objects. The failure to find a clear preference or apparent discrimination between these two stimuli after an initial exposure to one of them may be attributable to many factors. One that seems particularly important

Fig. 7. Control of distress vocalizations by shock and non-shock stimuli. Ducklings were initially imprinted to a single stimulus and later received shock in the presence of one of two stimuli. The histograms are based on the mean of the final three shock sessions. Distress vocalizations were calculated for a 10-sec period immediately before the onset of each stimulus (Pre-stimulus period) and during the first 10 sec of the presentation of that stimulus (Stimulus period). B-1 and B-2 received no shock.

is that in Klopfer's experiment, the paired stimuli were both continuously present, whereas in the present research, they were intermittently presented and withdrawn. During stimulus absence, the ducklings would typically move about the apparatus, distress calling, until the stimuli were again presented. Observations indicated that during the pre-shock choice tests, the ducklings would frequently remain on that side of the apparatus in which they were located when the stimuli were again presented. It seems reasonable that such behavior could be reinforced by presentations of the stimuli that occurred coincident with movements in a particular region of the apparatus. In this manner, as is the case with pole pecking, the onset of the stimuli could reinforce those behaviors occurring at the moment of stimulus onset. This feature of the procedure may be only one of many such contributing factors to the failure to find definite initial preferences in the present research.

Whatever the case, it is clear that there is substantial generalization in responsiveness to these stimuli prior to a history of differential experience. Whether response-independent shock could modify clear-cut choice behavior remains to be investigated. However, on the basis of research indicating that changes in preference can be accomplished by mere exposure to a second stimulus (Stratton, 1971; Salzen and Meyer, 1968), it seems likely that choice of a strongly preferred stimulus would also be suppressed by shock delivered in its presence or dependent on the choice of that stimulus.

GENERAL DISCUSSION

Past research and theory concerning the role of aversive stimuli in the context of imprinting have emphasized that shock both enhances responding (Kovach and Hess, 1963; Moltz *et al.*, 1959) and makes the imprinting experience

Fig. 8. Control of distress vocalizations by shock and non-shock stimuli. Ducklings were shocked in the presence of one of two stimuli from the first exposure to these stimuli. The data were analyzed as in Figure 7. The top portion represents those ducklings that received no shock. The lower panel contains the results of ducklings that were shocked in the presence of one stimulus.

more effective (Hess, 1964). On the basis of these findings, imprinting has been interpreted as being fundamentally different from associational learning (Eibl-Eibesfeldt, 1970; Hess, 1964). The present research attempted to analyze the effects of shock more systematically by examining whether differential shock schedules can modify the behavior of ducklings during and after imprinting.

Based on the present experiments, it seems reasonable to conclude that the delivery of electric shock to imprinted animals has relatively specific effects, differentially modifying selected responses in the duckling's behavioral repertoire and leaving other responses intact. As in other organisms, the schedule of shock presentation is of fundamental importance in determining the effect shock has on behavior (McKearney, 1968, 1969; Morse and Kelleher, 1970). The sensitivity of the imprinted animal's behavior to schedules of shock presentation makes it somewhat difficult to deal with the presumed general "strength" of imprinting when this is measured by predeter-

mined assumptions as to what best characterizes imprinting. Only certain responses temporally associated closely and consistently with shock appear to be suppressed. Such was the case, for example, in the third experiment where response-independent shock modified the behavior of remaining in the presence of a particular stimulus but had little effect on the control by both stimuli of distress vocalizations. A similar differential responsiveness was also obtained in Experiment I, although not mentioned specifically, in that both the stimuli controlling either following or not following were equally effective in suppressing distress calling. In spite of the fact that imprinting has been characterized by the individual or collective appearance of certain responses, there seems to be little basis for assuming that any one of these responses cannot be selectively suppressed without affecting what has generally been called imprinting. The present results suggest that events occurring in the presence of stimuli to which the duckling is exposed can modify behavior

that occurs when these stimuli are present. Any presumed reduction or enhancement of imprinting, either as an "underlying state" or more global response, has not been demonstrated. Aversive stimuli within the ranges used in the present study do not appear to disrupt or modify imprinting or "imprintability", but determine the temporal patterning of subsequent behavior rather precisely. It would appear that aversive stimuli have effects on the young organism in the context of imprinting that are analogous to those under other circumstances typically characterized as learning.

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