BEHAVIORAL CONTROL BY AN IMPRINTED STIMULUS¹

HOWARD S. HOFFMAN, JOHN L. SEARLE, SHARON TOFFEY,
AND FREDERICK KOZMA JR.

THE PENNSYLVANIA STATE UNIVERSITY

Newly hatched ducklings were exposed to imprinting procedures and subsequently trained to peck a key by presenting the imprinting stimulus as the reinforcing (response contingent) event. It was found that the key peck was learned only when imprinting procedures were initiated during the first 6 to 8 hr after hatch. Additional studies revealed that: (1) the duckling's distress vocalizations were reduced in the presence of the imprinting stimulus and enhanced in its absence; (2) when the ducklings had constant access to the imprinted stimulus (via a key peck), pecking responses occurred in bursts and relatively few distress vocalizations occurred; (3) the initial effect of extinction procedures was an increase in key peck rate. When, however, repeated key pecks failed to produce the imprinted stimulus, distress vocalization ensued and peck rate declined; (4) both the presentation of an unfamiliar mechanical figure and delivery of electrical shock enhanced distress vocalization and key pecks; (5) for some ducklings, certain familiar objects in the environment influenced distress calls in a manner comparable to the imprinted stimulus in that distress calls increased when these objects were removed.

The present experiments sought to employ imprinting as an avenue for research into the responses of young organisms to a parental figure. With the exception of Harlow and Zimmerman's (1958, 1959) pioneering work with infant monkeys, previous investigations of these responses have been largely limited to collecting and integrating clinical observations (Bowlby, 1958, 1960) or to analyzing ethological information (Hafez, 1962; Gottlieb, 1963; Sluckin, 1965). Many investigators have obtained data relevant to the interpretation of the parent-offspring relationship (Sluckin, 1965) but, in general, such data have been collected while investigating other issues.

In the work reported here, laboratory techniques were developed to investigate directly the affiliative relationship. The basic approach

applied the analytical tools of operant conditioning to elucidate the duckling's behavioral responses to an imprinted object. Presumably by experimentally elaborating the factors involved in these reactions it will be possible better to understand imprinting and the implications of imprinting for the interpretation of the primary social bond between the young organism and its parent.

EXPERIMENT I

Peterson (1960) and Campbell and Pickleman (1961) have shown that presentation of a previously imprinted stimulus could serve to reinforce operant responses for both chicks and ducklings. While Campbell and Pickleman raise questions as to whether prior imprinting experience is critical for this effect, neither they nor Peterson report data to support or deny the possibility that the stimulus used might reinforce subjects which had not been imprinted to it. The initial experiment of the present sequence replicated the major details of Peterson's experiment in which ducklings were taught to peck a key using presentation of a previously imprinted stimulus as the response contingent event. In addition, suitable control groups were run to insure that the observed behavioral effects were a product of the previous imprinting experiences.

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Subjects

Twenty-seven Peking ducklings (*A. platyrhynchos*) were hatched in isolation and maintained in individual brooder boxes (10 by 10 by 10 in.) with continuous access to food, water and a 40 w light bulb for heat and illumination. Subjects could hear but not see each other.

Apparatus

The original apparatus for imprinting and key peck training was similar to the automated equipment described by Peterson, except that it was hand operated. After an initial replication of Peterson's procedure was completed, the apparatus was redesigned, and two automated units were constructed. They were housed in individual sound-treated and temperature-controlled rooms. The work done in the original apparatus was replicated in the new units, and as the results were almost identical, they are not reported separately.

The automated apparatus is shown in Fig. 1. These units consisted of plywood boxes (6 by 2.5 by 2.5 ft) divided lengthwise into runways for the duck (6 by 1.5 by 2.5 ft) and compartments for the imprinting stimulus (6 by 1 by 2.5 ft), separated by a partition of brass screening (#60 mesh). The lighting (40 w, 110 v, G.E. cool white fluorescent bulbs) in the two compartments was arranged so that its interaction with the brass screening provided a one-way vision effect. When the light was on in the duckling's runway and out in the stimulus compartment, the reflection from the screen prevented the subject from viewing the stimulus compartment; when the lighting was reversed, the stimulus compartment and its contents became visible from the duckling's runway. "Stimulus presentation" consisted of illuminating the stimulus compartment and

Fig. 1. Apparatus for imprinting and key peck training. The objects on the right side of the subject's alley are food and water dishes which were always present and filled.

moving the stimulus at approximately 1 ft per sec along the length of the compartment.

The stimulus consisted of a white plastic milk bottle (3 by 3 by 8 in.) mounted over and completely covering the superstructure of a model train engine which ran the length of the stimulus compartment on HO gauge track. The stimulus run could also be confined to a 3-ft section in the center of the compartment, to keep the stimulus near the key during the final stage of key peck training and during all subsequent experiments.

Responses were detected with an enclosed, back-illuminated Gerbrands' pigeon key mounted just in front of the screen separating the subject's runway and the stimulus compartment. Its height above the runway floor was adjustable to accommodate different size ducklings. A bank of relays, steppers, timers, and recorders programmed reinforcements and recorded responses.

Procedure

Subjects were assigned randomly to four groups. Figure 2 is a schematic representation of the several procedures for each group. Groups I, II, and IV each contained seven ducklings, Group III contained six. As seen in Fig. 2, four procedures were used. Imprinting procedures exposed the duckling to the illuminated moving stimulus. Familiarization procedures exposed the duckling to the illuminated, but empty, stimulus compartment; the stimulus having been removed. Key peck training, using the imprinted stimulus, consisted of il-

Fig. 2. Schematic representation of the procedures for each of the several groups. "N" refers to number of subjects.

luminating the stimulus compartment and presenting the moving stimulus whenever behavior approximated a key peck; *i.e.*, the experimenter observed the duckling and attempted to develop the key peck, using presentation of the moving stimulus as the response contingent event. Key peck training without an imprinted stimulus consisted of illuminating the empty stimulus compartment whenever behavior approximated a key peck; *i.e.*, the experimenter observed the duckling and attempted to develop the key peck using presentation of the empty stimulus compartment as the response contingent event.

The rationale for the experimental design derives from the observation that unless subjects are exposed to the imprinting stimulus during the critical period for imprinting (approximately the first 24 hr after hatching), subjects will not imprint to the stimulus (Hess, 1964). The present design utilizes this factor by comparing the reinforcing effects of an imprinting stimulus initially presented during the critical period (Group I: early imprinting, early training) to the reinforcing effects of that stimulus when the initial exposure occurs well past the critical period (Group II: late imprinting, late training).

Group III (early imprinting, late training) provides a control for the age differences in Groups I and II during key peck training. Group IV (early familiarization, late training) controls for the possibility that observed differences between early *vs.* late imprinted groups is due to differences in age when the ducklings first became familiar with the apparatus.

Imprinting sessions lasted 45 min and each subject received six approximately equally spaced sessions within a 48 hr interval. For ducklings exposed to early imprinting, the first session always occurred within 6-8 hr after hatching to insure that the subject was exposed to the moving stimulus during the critical period for imprinting. Familiarization sessions followed the same temporal pattern as imprinting sessions except that the moving stimulus was not present. For both familiarization and imprinting procedures the key was removed from the apparatus.

Key peck training sessions for Groups I, II, and III lasted 1.5 hr each. The response contingent event initially consisted of a 12-sec presentation of the moving stimulus. If, however, a subject pecked the key, stimulus presen-

tation was reduced to 5 sec and the stimulus run was confined to the center section of the track. This procedure typically precluded overt following behavior. Ducklings in Group I (early imprinting, early training) and Group III (early imprinting, late training) received two training sessions at the times indicated in Fig. 2; Group II (late imprinting, late training) received only one. Ducklings in Group IV (early familiarization, late training) initially received two 45-min training sessions with illumination of the familiar empty stimulus compartment serving as the response contingent event. Finally, to test the possibility that a novel moving stimulus in familiar surroundings might reinforce key pecks, Group IV subjects received a 45-min training session with presentation of the moving stimulus serving as the response contingent event.

Results

The results may be simply summarized. Every duckling in Group I (early imprinting, early training) and in Group III (early imprinting, late training) learned to peck the key. Since none of the ducklings in the other groups could be taught to peck the key, it is concluded that the reinforcing effects of an imprinted stimulus derive from events that transpire during the critical period for imprinting and are not attributable to intrinsic properties of the stimulus *per se*. The details of the results further support this conclusion.

During the first session of imprinting, all of the animals in Group I (early imprinting, early training) and Group III (early imprinting, late training) began to follow the moving stimulus within 15 min; in the second imprinting session, all were following at least 50% of the time. By the sixth imprinting session, all were following at least 75% of the time. None in Group II (late imprinting, late training) followed at all during any of the imprinting sessions, and Group IV (early familiarization, late training) moved about very little during the procedures to familiarize them with the illuminated empty stimulus compartment.

Key peck training was accomplished with the subjects exposed to early imprinting (Groups I and III). By the end of the first training session all ducklings in these groups were consistently hovering near the key and several in both groups were occasionally pecking. Most of the rest were emitting behavior

which approximated the key peck, *i.e.*, touching the key with their bill, but not forcefully enough to activate the circuits. During the subsequent training session, the probability of key peck increased until all of the subjects in Group I (early imprinting, early training) were emitting at least 10 responses per min. A similar rate was developed by two members of Group III (early imprinting, late training), and although the rest were pecking the key, their rate was low and sporadic.

The behavior of Group II (late imprinting, late training) was very different. None of these ducklings had followed the stimulus at any time during imprinting procedures, nor could any be taught to approach the key, much less to peck. During training they spent most of their time huddled in a corner of the runway. Occasionally, they would turn toward the key or move in its direction, but stimulus presentation did not affect the probability of this behavior. Since there was no evidence that the imprinting stimulus reinforced any of the subjects of Group II, attempts to train them were discontinued after the initial 1.5 hr session.

When the ducklings in Group IV (early familiarization, late training) were exposed to training, with illumination of the empty stimulus compartment serving as the response contingent event, it appeared at first as if stimulus presentation was serving as a weak reinforcement: some subjects were induced to remain near the key by presenting the empty stimulus compartment when the duckling was near the key. After the first 10 min of the session, however, presentations of the illuminated empty compartment had no further observable reinforcing effects. The ducklings left the vicinity of the key and no key pecks were produced by any members of this group during either of the first two training sessions. In the third training session, when presentation of the moving stimulus served as the response contingent event, these ducklings showed little reaction to the stimulus; its presentation had no observable reinforcing effect on their behavior, and again, no pecks were emitted. This negative result is similar to that obtained with the ducklings in Group II (late imprinting, late training).

Discussion

The procedures for Group I (early imprinting, early training) replicated those used by Peterson (1960). The present results confirm

Peterson's findings in that they indicate that presentation of a previously imprinted stimulus is adequate reinforcement to develop key pecking behavior. The finding that ducklings in Group III (early imprinting, late training) also learned the key peck means that once imprinting has occurred, the reinforcing effects of stimulus presentation are maintained over at least a six-day interval when the duckling has no contact whatever with the imprinted stimulus.

Hess (1964) has reported that with ducklings, maximal imprinting occurs when subjects are exposed to the imprinting stimulus at approximately 13-16 hr of age and that if the initial exposure occurs after 24 hr of age, imprinting is not likely to occur. The negative results with Group II (late imprinting, late training) are consistent with Hess's finding. Finally, the failure of Group IV (early familiarization, late training) to learn the key peck suggests that the negative results with Group II (late imprinting, late training) are not due to subject's lack of familiarity with the apparatus. This factor also supports the conclusion that the reinforcing effects of an imprinted stimulus are derived from events which transpire when imprinting takes place.

EXPERIMENT II

When immature ducklings (like the infants of many species) are separated from their mother, they emit a series of harsh peep-like sounds. This form of vocalization, the distress call, is thought to indicate autonomic responses to aversive conditions, in that it also occurs when the duckling is threatened by a predator, exposed to reductions in body temperature, deprived of nourishment, or subjected to painful stimulation (Hafez, 1962; Sluckin, 1965).

In the course of key peck training in Exp I, the imprinted ducklings emitted many distress calls when the imprinted stimulus was removed. These calls subsided when the stimulus was again presented. Experiment II sought to analyze more thoroughly the way in which presentation and withdrawal of a previously imprinted stimulus influences distress calls. A second phase of Exp II assessed the effects of extinction procedures on distress vocalization when subjects were pecking a key to produce the imprinted stimulus.

Subjects

Six naive Peking ducklings (*A. platyrhynchos*) were hatched in isolation and initially maintained in the same brooder boxes used for Exp I.

Apparatus

The units for imprinting and key peck training were the ones used in Exp I, modified so that distress calls could be recorded. In the duckling the distress call has a relatively restricted frequency range (approximately 3000 to 4000 cps) and is relatively intense; hence, it can be reliably detected if the input to a sensitive voice-operated relay is selectively filtered. Two such relays were used, one for each apparatus. Two microphones were used for each relay. They were placed 3 ft apart and were located 3 ft in front of the duckling's alley. This arrangement prevented the voice keys from responding differentially when subjects were located in different parts of the alley. Finally, in order to insure that the voice keys would selectively respond to distress calls and not to other sounds, several pilot subjects were placed in the apparatus and repeatedly captured and released. During capture, subjects emitted a constant stream of distress calls and the voice key consistently responded to them. Movements of the imprinted stimulus, however, and other sounds of the subject (*i.e.*, the low inten-

sity contentment cheep) never activated the voice key.

Procedure

Using the techniques employed with Group I of Exp I, three of the subjects were imprinted and subsequently trained to peck the key. The three others were imprinted, but received no key peck training. Phase I of Exp II compared the two groups to determine how the tendency to emit distress calls was related to presentation and withdrawal of the imprinted stimulus. Phase II examined the effects of short term extinction procedures on the ducklings which had been trained to key peck.

Results

Phase I. Figure 3 shows the typical pattern of distress calls recorded during presentation and withdrawal of the imprinted stimulus from the three imprinted ducklings that were not trained to key peck. The records were obtained on the seventh day from hatch. As can be seen, subjects began to emit distress calls shortly after the imprinted stimulus was withdrawn, and continued to do so until the stimulus was again presented. These data corroborate the findings of Moltz (1960) and others (see Sluckin, 1965) which indicate that when subjects have been imprinted, the tendency to emit distress calls is determined by the proximity of the imprinted stimulus.

Fig. 3. Distress vocalization as influenced by the presentation and withdrawal of the imprinted stimulus.

Figure 4 shows (on a more condensed time scale than Fig. 3) the pattern of key pecks, reinforcements, and distress calls exhibited by the subjects that were imprinted and also key peck trained. The records were obtained on the seventh day from hatch, under conditions in which each peck yielded a 5-sec exposure of the moving imprinted stimulus. For these ducklings, key peck responses tended to occur in bursts, and few distress calls were emitted.

This behavioral pattern stands in sharp contrast to the rapid and prolonged emission of distress calls which occurs when subjects have no way of producing the imprinted stimulus (as in Fig. 3). Apparently when ducklings have constant access to the imprinted stimulus via a key peck, its extended absence does not necessarily lead to emission of distress calls.

Phase II. Figure 5 shows typical patterns of key pecks, reinforcements, and distress calls produced by each of the trained subjects when extinction procedures were administered in the midst of a burst of key pecks. The initial effect is a rapid increase in the number of pecks. This is followed, somewhat later, by a large increase in distress calls. With continued extinction, peck rate begins to decline, but the rate

of emitted distress calls remains at a relatively high level until pecks again produce the imprinted stimulus.

These results are of particular interest because they imply that increases in distress vocalization are not solely determined by the stimulus change that occurs when the imprinted stimulus is withdrawn. As seen in Fig. 5, the distress call shows no increase until several seconds after the final pre-extinction stimulus presentation. Indeed, distress calls show an increase only after the duckling has made a large number of unreinforced key pecks.

Discussion

It is difficult to determine whether, during extinction, the eventual increase in distress calls is due to the failure of pecks to produce the imprinted stimulus, or whether the increase is due merely to the extended absence of the imprinted stimulus. Regardless of the explanation, the close correspondence between availability of the imprinted stimulus and emission of distress calls is additional evidence that the imprinted stimulus is an important agent in the control of the duckling's distress vocalization; they suggest that the availability

Fig. 4. Distress vocalization and key pecking when each peck exposed the imprinted stimulus for 5 sec.

Fig. 5. Key pecks and distress vocalizations during short term extinction procedures when pecks were no longer followed by presentation of the imprinted stimulus.

of the stimulus, via the key peck, contributes to this control.

EXPERIMENT III

Moltz, Rosenblum, and Halikus (1959), and Kovach and Hess (1963) have noted that presentation of an aversive stimulus (*e.g.*, electrical shock) during imprinting procedures enhanced subjects' tendency to follow the imprinted stimulus. In addition, Harlow and Zimmerman (1958 and 1959) report that presentation of a novel and presumably aversive, doll-like toy enhanced the tendency of infant monkeys to cling to a mechanical surrogate mother. Experiment III sought to examine the ducklings' reactions to a novel doll-like figure and to electrical shock when they had constant access to the imprinted stimulus via a key peck.

METHOD

Subjects

The same three trained ducklings exposed to extinction procedures in Exp II were used.

Apparatus

The equipment from Exp II was used. Electrical shock was administered to the duckling across the thighs via light wires (28 gauge) coated with electrode jelly and taped in place. Shock was generated by an Applegate constant-current stimulator set to deliver 2 ma. The mechanical figure was similar to the one used by Harlow and Zimmerman (1958 and 1959) when they sought to employ aversive procedures with infant monkeys.

Procedure

One of the ducklings was repeatedly tested for its reaction to the introduction of the mechanical figure during periods between response bursts. The two others were tested for the effects of electrical shock in an extended (10 hr) session when a 0.5-sec pulse of shock was presented once every 24 min. In this condition, delivery of electrical shock was independent of behavior and of the presence or absence of the imprinted stimulus. Throughout all tests, distress calls, key pecks, and reinforce-

ment were recorded. Each peck exposed the imprinted stimulus for 5 sec.

Figure 6 shows the typical effects of placing the mechanical figure at one end of the alley during an interval when the duckling was not responding to the key. The subject immediately began to emit distress calls and shortly thereafter began to peck. It continued to peck as long as the mechanical figure was present. The middle section of Fig. 6 illustrates the typical effects of entering the duckling's room. These effects are amplified somewhat because the experimenter also scratched on the outside wall of the chamber. As can be seen, disturbing the duckling's routine initiates an immediate burst of distress calls followed by key pecks. The bottom section of this figure shows a second example of the effects produced by introducing the mechanical figure. It further illustrates the stability of the distress vocalization and key pecking reactions induced by the presentation of a novel, and presumably aversive, stimulus. As seen in Fig. 6, when key pecks and distress calls are induced by experimenter-controlled disturbances, distress vocalizations occur almost immediately and do not necessarily

subside until several seconds after the disturbance has terminated.

Figure 7 shows the pattern of distress calls and reinforced key pecks for the two 18-day-old ducklings tested for the effects of electrical shock. The top half of Fig. 7 shows the mean number of pecks in the various 2-min intervals that preceded and followed the several shocks. The bottom section of Fig. 7 shows the number of distress calls emitted during these same intervals. Each shock produced an immediate burst of distress calls and a few seconds later, an abrupt elevation in the tendency to peck the key. For both subjects, the number of distress calls dropped almost to zero within the first minute or so, whereas key pecks persisted (at a decreasing rate) for many minutes.

Discussion

These data complement the findings of Moltz *et al.* (1959) and Kovach and Hess (1963) by indicating that electrical shock enhances the tendency to approach the imprinted stimulus even when the approach response involves a learned behavior (the key peck). Since the response facilitation obtained here is diametri-

Fig. 6. Key pecks and distress calls during aversive procedures. The top and bottom sections show the influence of presenting a novel mechanical figure. The middle section shows the effects of entering the subject's room and scratching on the wall of the chamber.

Fig. 7. Temporal pattern of distress vocalizations and key pecks when a pulse of electrical shock was delivered once every 24 min. The ordinates show the mean number of responses in the several 2-min intervals that preceded and followed the delivery of each shock.

cally opposite to the suppression of responses typically observed when electrical shock is presented to subjects performing food-reinforced behavior (Estes and Skinner, 1941), it seems apparent that reinforcement afforded by the sight of the imprinted stimulus is qualitatively different from that afforded by food. Indeed, the present response facilitation is similar to that obtained by Sidman, Herrnstein, and Conrad (1957) when unsignaled shocks were presented to subjects performing a response which permitted them to postpone shocks. In this respect, responses which produce the imprinted stimulus are similar to responses which postpone or terminate aversive conditions.

EXPERIMENT IV

When permitted continuous access to the imprinted stimulus via a key peck, two of the subjects in Exp III were observed to spend most of their time in the alley directly in front of the key. Moreover, they would almost always go directly to this position after eating or drinking, even during extended periods when no pecks were emitted. This suggested that the stimulation from the key itself might be exert-

ing some form of control over behavior. In Exp IV this possibility was tested by removing the key and assessing the resultant tendency to emit distress calls.

Subjects

The three subjects from Exp III were used. They were 18 days old at the beginning of Exp IV.

Procedure

After Exp III, subjects lived continuously in the apparatus for seven days. Except for routine cleaning and feeding, they were undisturbed and had continuous access to food, water, and the key. Under these conditions the imprinted stimulus was always available; each key peck produced it for 5 sec. Tests for the effects of key removal occurred on day 8. All three subjects received the same testing sequence: (1) food and water dishes were removed for 15 min; (2) the key was removed for 15 min; (3) food and water dishes were again removed for 15 min; and (4) the key was again removed for 15 min.

Results

Figure 8 shows the pattern of key pecks, reinforcement, and distress calls produced by one of the ducklings during the several operations. Removal of the key was accompanied by a large number of distress calls, which persisted until the key was replaced. A few key pecks occurred when the key was replaced, but these did not persist for an extended period. Removal of the food and water dishes had a much weaker effect and the distress calls terminated shortly after the removal. It is of interest that these subjects were first exposed to the key on day 4. It is clear, therefore, that while the behavioral control exercised by the key may have derived from its association with the imprinted stimulus, this control is not a product of subjects' contact with the key during the critical period for imprinting.

When the several operations were replicated with the two other subjects, one of them consistently provided records virtually identical to those in Fig. 8. The third subject was less influenced by the presence or absence of the key and its reaction to key removal was transient, in that it resembled the response of the other two subjects to removal of food and water dishes. This subject spent most of its time in a

Fig. 8. Distress vocalization and (when possible) key pecks during the removal of (1) the food and water dishes and (2) the key.

corner of the alley and seldom remained near the key except during response bursts. Hence, it was not expected that the presence of the key would have a strong influence on this subject's behavior.

Discussion

Hess (1964) has reported that certain stationary objects in the subject's environment can become involved in an imprinting-like process, in that the subject may show dispositions to approach them as a result of early exposure. Also, Taylor and Sluckin (1964) report that chicks reared in individual pens may form an attachment for certain familiar stimulus configurations within their environment. The effects of the key on two of the subjects are consonant with these findings. The present results also indicate that these effects do not necessarily depend upon contact with the stimulus configuration during the critical period for imprinting. Finally, the failure to find a comparable effect in the third duckling suggests that the effects of the key are idiosyncratic, and may depend upon the factors that determine the part of the apparatus which the subject adopts as its base. At present, little is known about these factors.

While this study provides no direct information about the relative importance of the key *vs.* the imprinted stimulus as sources of behavioral control, it can be noted that in Exp III, aversive procedures heightened the tendency to work for the imprinted stimulus despite the continued presence of the key. This suggests that the control exerted by the imprinted

stimulus is probably stronger than that afforded by the key.

EXPERIMENT V

During the previous studies, it was observed that unless disturbed by external sounds or by the experimenter during routine cleaning and feeding, subjects tended to emit few distress calls when in their brooder boxes. This suggested that the brooder box itself might be serving as a supplementary source of behavioral control. Experiment V examined this possibility.

Subjects

Three naive Peking ducklings were hatched in isolation, imprinted, and trained to key peck using the procedures of Group I, Exp I.

Apparatus

The basic equipment was the same as used in Exp IV. In addition, a movable three-sided replica of the subject's brooder box was placed at one end of the subject's alley. The replica, like the original, included a light bulb and food and water dishes. Food and water were also available from dishes at the other end of the alley.

Access to the replica brooder could be controlled by removing it, by placing a transparent screen in front of it (physical, but not visual isolation) or by placing an opaque partition in front of it (physical and visual isolation). Access to the distant food and water dishes could also be controlled by a partition.

Procedure

When imprinting and key peck training were completed, subjects were permitted to live in the apparatus with continuous access to the imprinted stimulus via a key peck and with the replica brooder box in place. Except for routine cleaning and feeding, subjects were undisturbed for a period of seven days. As in previous studies, each key peck exposed the moving imprinted stimulus for 5 sec. Tests for the effects of the replica brooder began on the 10th day from hatch. These tests included physical but not visual isolation from the food and water dishes, and from the replica brooder, both physical and visual isolation from these objects, and removal of these objects from the apparatus. All subjects received several replications of the same sequence of tests and each test was administered during an interval between bursts of key peck responses. Finally, all subjects were tested for the effects of the key (as in Exp IV). Throughout all but this final test, subjects had continuous access to the key, and hence, to the imprinted stimulus.

Results

Only one of the three ducklings adopted the replica brooder box as its home base. The other two ducklings located themselves near

the front wall of the apparatus and were typically seen with their back to the key. All three subjects, however, exhibited a pattern of key pecks and distress calls essentially the same as in Fig. 4. Key peck responses tended to occur in bursts and few distress calls were emitted. After the first two days, each subject spent most of its time at its adopted base, generally leaving the base only to peck the key or occasionally to eat and drink from the second supply of food at the far end of the alley.

Figure 9 shows the typical pattern of distress calls, key pecks, and reinforcements during the several tests for the subject that adopted the replica brooder as home base. Only removal of the replica brooder, and placing the opaque partition in front of it (both physical and visual isolation) produced a continued elevation in the rate of key pecks and in distress calls. Physical, but not visual, isolation from the replica brooder box produced a pattern of pecking and distress calls similar to that generated by blocking the subject from the food and water dishes at the far end of the alley. It is of interest, however, that when the screen blocked the entrance to the replica brooder, the subject stationed itself at the screen facing the visible, but inaccessible, brooder.

When the other two subjects were tested for the effects of the replica brooder, neither gave

Fig. 9. Distress vocalization and key pecks during isolation from the replica brooder and the food and water dishes.

more than transitory reactions to any of the several procedures. Finally, when tests were conducted for the effects of key removal, none of the subjects displayed much agitation. Apparently, the reactions to the replica brooder, like those in Exp IV to the key, are idiosyncratic and depend upon which part of the apparatus the subject adopts as home base.

Discussion

These data reinforce the conclusions of Exp IV, and further indicate that when objects other than the imprinted stimulus control behavior, this control is not necessarily derived from a direct association between these objects and the imprinted stimulus. In the present experiment, the brooder box was physically distant from the key; a condition which necessitated that the subject leave the brooder box in order to produce the imprinted stimulus. This factor would tend to minimize any association between the brooder box and the imprinted stimulus.

SUMMARY AND CONCLUSIONS

The results of the several studies may be summarized as follows:

1. The capacity of an imprinted stimulus to serve as a reinforcement derives from events that occur during the critical period for imprinting.
2. The imprinted stimulus exercises control over distress calls in that its withdrawal leads to heightened distress vocalizations which terminate with its presentation.
3. When the duckling has constant access to the imprinted stimulus, via a key peck, pecking responses tend to occur in bursts and few distress calls are emitted, even during extended intervals between bursts. If, however, key pecks fail to produce the imprinted stimulus, the subject initially pecks more rapidly and then begins to emit distress calls.
4. Aversive procedures heighten subjects' tendency to perform the response which produces the imprinted stimulus.
5. For some ducklings, various objects, in addition to the imprinted stimulus, can acquire control over the subjects' behavior in that distress vocalization and/or key pecking is reduced in the presence of these objects and enhanced when the objects are withdrawn.

These findings indicate that the behavioral

control exerted by the imprinted stimulus is a product of imprinting *per se*, and that the imprinted stimulus more or less continuously regulates behavior. Apparently it does so in somewhat the same way that food influences behavior. When, for example, an organism is deprived of food, food-directed behavior increases in probability. A similar enhancement of behavior directed toward an imprinted stimulus occurs when the imprinted stimulus is withheld. Moreover, when the subject has free access to food, eating is not continuous, but occurs in bursts. A comparable pattern emerges when the subject has free access to the imprinted stimulus. There is, however, one important difference between behaviors controlled by the imprinted stimulus and those controlled by food. Aversive stimulation enhances behavior directed toward the imprinted stimulus, whereas food directed behavior is typically suppressed by aversive procedures.

At present, little is known about the dynamics of the behavioral control exerted by an imprinted stimulus, but the close correspondence between distress calls and the presence or absence of the imprinted stimulus suggests that responses which produce the imprinted stimulus probably serve to terminate aversive conditions which develop when the imprinted stimulus is withdrawn. Apparently, aversive stimuli such as electrical shock or novel objects, facilitate responses which produce the imprinted stimulus by enhancing the aversive conditions on which these responses are based. The present work also reveals that for some ducklings a similar dynamics may operate with certain familiar objects (e.g., the key and/or the brooder box) in that the withdrawal of these objects generates an aversive condition which enhances both distress vocalization and approaches to the imprinted stimulus via the key peck. Even less is known about the variables responsible for this last effect.

REFERENCES

- Bowlby, J. The nature of the child's tie to his mother. *Internat. J. Psycho-anal.*, 1958, **39**, 1-24.
- Bowlby, J. Separation anxiety. *Internat. J. Psycho-anal.*, 1960, **41**, 89-113.
- Campbell, B. A. and Pickleman, J. R. The imprinting object as a reinforcing stimulus. *J. comp. physiol. Psychol.*, 1961, **54**, 592-596.
- Church, R. M. The varied effects of punishment on behavior. *Psychol. Review*, 1963, **70**, 369-402.

- Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **29**, 390-400.
- Gottlieb, G. A naturalistic study of imprinting in wood ducklings (*Aix sponsa*). *J. comp. physiol. Psychol.*, 1963, **56**, 86-91.
- Hafez, E. S. E. *The Behavior of Domestic Animals*. London: Baillere, Tindall, and Cox, 1962.
- Harlow, H. F. and Zimmermann, R. R. The development of affectional responses in infant monkeys. *Proc. Amer. Phil. Soc.*, 1958, **102**, 501-509.
- Harlow, H. F. and Zimmermann, R. R. Affectional responses in the infant monkey. *Science*, 1959, **130**, 421-432.
- Hess, E. H. Imprinting in birds. *Science*, 1964, **146**, 1128-1139.
- Jaynes, J. Imprinting: The interaction of learned and innate behavior. II: The critical period. *J. comp. physiol. Psychol.*, 1957, **50**, 6-10.
- Kovach, J. K. and Hess, E. H. Imprinting: effects of painful stimulation upon the following response. *J. comp. physiol. Psychol.*, 1963, **56**, 461-464.
- Moltz, H., Rosenblum, L., and Halikas, N. Imprinting and level of anxiety. *J. comp. physiol. Psychol.*, 1959, **52**, 240-244.
- Moltz, H. Imprinting: empirical basis and theoretical significance. *Psychol. Bull.*, 1960, **57**, 291-314.
- Peterson, N. Control of behavior by presentation of an imprinting stimulus. *Science*, 1960, **132**, 1295-1396.
- Sidman, M., Herrnstein, F. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shocks. *J. comp. physiol. Psychol.*, 1957, **50**, 553-557.
- Sluckin, W. *Imprinting and Early Learning*. Chicago: Aldine Publishing Company, 1965.
- Taylor, K. F. and Sluckin, W. An experiment in tactile imprinting. *Bull. Brit. psychol. Soc.*, 1964, **17**, No. 54, 10A.

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