REINFORCEMENT BY AN IMPRINTING STIMULUS VERSUS WATER ON SIMPLE SCHEDULES IN DUCKLINGS

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Ducklings (5 to 28 days old) were trained to peck a pole on fixed-ratio, fixed-interval, and multiple schedules using brief presentation of an imprinting stimulus as the response-contingent event. Other ducklings of the same age were trained similarly except that reinforcement consisted of access to water. With water reinforcement the typical fixed-ratio ("break-run"), fixed-interval ("scallop"), and multiple schedule response patterns were readily established and consistently maintained. With the imprinting stimulus these schedule effects were inconsistent in some subjects and virtually nonexistent in others, despite extended training. Schedule control with the imprinting stimulus was not improved by the use of a reinforcement signaling procedure which enhances responding reinforced by electrical brain stimulation on intermittent schedules. However, the overall rates of responding and the extinction functions generated after reinforcement with water versus the imprinting stimulus were comparable. These findings imply that control by temporal and discriminative stimuli may be relatively weak when a young organism's behavior is reinforced by presentation of an imprinting stimulus.

Key words: imprinting stimulus, water reinforcement, fixed-ratio schedules, fixed-interval schedules, multiple schedules, extinction, pecking, social reinforcement, stimulus control, attention, ducklings

The reinforcement provided by presentation of an imprinting object can establish and maintain a variety of types of operant behavior. In most of the reported investigations of this phenomenon, however, the behavior maintained by the imprinting object was studied under conditions in which every instance of the defined response produced presentation of the stimulus (see DePaulo & Hoffman, 1980, for a review of these studies). Fixed-ratio schedules were employed in two investigations (Eiserer, Hoffman, & Klein, 1975; Peterson, 1960, 1962), but neither reported the extent to which the "break-run" pattern characteristic of fixed-ratio performance with conventional

reinforcers (food or water) developed with reinforcement by the imprinting stimulus. The research reported here addressed this issue. It also sought to determine whether the "scallop" fixed-interval pattern usually obtained with conventional reinforcement could also be obtained with an imprinting stimulus.

EXPERIMENT 1

Experiment 1 examined ducklings' responding on fixed-ratio (FR) and fixed-interval (FI) schedules for presentation of an imprinting stimulus. The intermittent schedules were introduced when the ducklings were very young because prior research has suggested that the reinforcing capacity of an imprinting stimulus may wane as the subjects mature (Hoffman & Kozma, 1967). Other ducklings of the same age were studied under similar conditions except that reinforcement consisted of access to water instead of presentation of an imprinting stimulus. This group was included in order to determine whether typical FR and FI schedule effects could, in fact, be obtained with a conventional reinforcer under these circumstances.

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METHOD

Subjects

The subjects used in all of the experiments in this report were Khaki Campbell ducklings (*Anas platyrhynchos domesticus*) hatched from eggs obtained from George F. Shaw, Inc., West Chester, Pennsylvania. The eggs were hatched in visual isolation in a forced-air incubator.

In Experiment 1, 13 ducklings were used. Five of these subjects were assigned to a condition in which access to water served as reinforcement for operant responding and the other eight were assigned to a condition in which reinforcement consisted of presentation of an imprinting stimulus.

Apparatus

Each duckling was housed in a separate unit that consisted of a 60-l white translucent plastic container lined with a clear polyethylene bag. Each unit was partially filled with absorbent bedding and contained food and water dishes. For subjects afforded water reinforcement, the food and water dishes in their units were removed during periods when deprivation was required. In addition, each of their units contained a yellow ball (7-cm diameter) suspended 3 cm above the floor. Its purpose was to provide a social surrogate object for these birds who, otherwise, would have no exposure to this type of stimulation.

The experimental chamber used to study reinforcement by an imprinting stimulus consisted of a plywood box (140 by 64 by 74 cm) divided lengthwise by a fine-mesh stainless-steel screen into approximately equal compartments, one for the duckling and one for the imprinting stimulus. Lighting in the subject compartment was provided by two continuously illuminated 75-W incandescent lamps mounted above the screen. These lamps were positioned so that unless the stimulus compartment was also illuminated, the light which reflected from the screen prevented the subject from viewing its contents.

The imprinting stimulus consisted of a white, rectangular, foam rubber covering (22 by 10 by 10 cm) mounted over a model train engine which ran back and forth within the middle 65 cm of an HO gauge track that traversed the length of the stimulus compartment. Presentations of the stimulus were pro-

duced by illuminating two overhead 75-W incandescent lamps in its compartment and moving the stimulus along its track at approximately 30 cm/sec. Stimulus withdrawal was accomplished by extinguishing the overhead lamps and stopping the movement of the stimulus. A balsa-wood pole (1 by 1 by 30 cm) was attached to a pigeon key mounted on the wall above the center of the screen. The pole hung vertically down to the floor of the subject compartment, and was recessed within a channel through the screen to prevent the duckling from hitting the pole by movements (e.g., wing flaps) other than pecks. The peck force required to operate the pigeon key was approximately 2 g. Responses on the pole initiated stimulus presentation for a duration determined by the setting of a timer. The bottom 7.5 cm of the pole consisted of a strip of translucent plastic behind which were mounted three "grain-of-wheat" bulbs. By illuminating the bulbs this section of the pole could be lit to provide a visual stimulus. A closed-circuit television system permitted observation of subjects during experimental sessions.

The experimental chamber used to study water reinforcement was basically the same as the chamber used to study reinforcement by an imprinting stimulus. It differed in that its stimulus compartment was never illuminated and that its subject compartment contained a suspended rubber ball to serve as a surrogate companion. The system for the delivery of water reinforcement consisted of a 20-l reservoir and an electrically operated valve (both mounted above the chamber), a funnel, and a container for collecting surplus water. When the valve was opened, water flowed through plastic tubing from the reservoir to the lip of the funnel (located adjacent to the pole) where it spiraled downward before emptying into a drainage container (located underneath the chamber). With this arrangement the water was available only so long as the valve was operating, and the system was self-cleaning. The chamber also contained a small tray (15 by 7 by 4 cm) filled with food (dry mash). It was located adjacent to the pole on the side opposite to the funnel.

Procedure

Each duckling assigned to the condition with reinforcement by the imprinting stimulus was removed from the incubator at approxi-

mately 12 to 18 hr posthatch and individually placed into the appropriate experimental chamber for a 30-min "imprinting session" during which the moving imprinting stimulus was continuously present behind the screen. Over the first two days posthatch, three additional 30-min imprinting sessions were administered. On Days 3 and 4 posthatch each duckling was trained to peck the pole for presentation of the imprinting stimulus by the method of successive approximations (shaping). During these procedures, the experimenter watched the duckling via closed-circuit television and presented the stimulus very briefly (approximately .5 sec) when the bird approached the pole. Once the duckling was in the vicinity of the pole, only movements which more and more closely resembled a pole peck were reinforced until the duckling actually pecked the pole. Each response on the pole produced the stimulus for 10 sec. Since the timer controlling reinforcement duration did not reset when any additional responses occurred during stimulus presentation, the imprinting object could not be kept continuously present. After the response was established, each duckling was allowed 1 to 2 hr of unrestricted responding under continuous reinforcement (CRF).

On Days 5 to 14 posthatch the ducklings were run in daily sessions, 90 min in duration, of unrestricted pole-pecking reinforced by 10-sec presentations of the imprinting stimulus. Four ducklings were studied on FR schedules (FR-imprinting group) and were exposed to the following sequence of schedules over Days 5 to 7 posthatch: CRF, FR 5, FR 10, FR 20, FR 30; throughout the subsequent sessions (Days 8 to 14) the FR 30 schedule remained in effect. The other four subjects (FI-imprinting group) were exposed to CRF, FI 10-sec, FI 20-sec, FI 40-sec, and FI 60-sec schedules over Days 5 to 6 posthatch; throughout Days 7 to 14 the FI 60-sec schedule remained in effect.

Before the start of each session, the imprinting stimulus was switched on and the duckling was placed in the chamber with the stimulus present. Approximately 30 sec later the imprinting stimulus was withdrawn (independently of the duckling's behavior) and throughout the rest of the session exposure to the stimulus was response-contingent. Since presentation of an imprinting stimulus engenders "priming" aftereffects (Eiserer & Hoff-

man, 1973), the brief period of exposure to the imprinting stimulus at the start of the session served to increase the likelihood that the subject would begin responding early in the session.

For subjects in the water reinforcement condition, an attempt was made to use procedures that closely paralleled the procedures used with the ducklings afforded reinforcement by the imprinting stimulus. Thus, on Days 1 and 2, when the ducklings in the latter condition were given four 30-min sessions of continuous exposure to the imprinting stimulus, the ducklings assigned to the water reinforcement condition were given four 30-min sessions of "continuous exposure" to the water in their chamber. During these sessions the funnel was corked and filled with water. On Day 3 the cork was removed from the funnel, and the ducklings were allowed to become accustomed to drinking from the running stream that resulted when the water delivery system was operated. The shaping of the pole peck with water reinforcement was then conducted. Throughout reinforcement the lower section of the pole was illuminated to provide a stimulus to indicate that water was flowing. The first pecks automatically produced water for 2 sec, but as pecks became more frequent the duration of the reinforcer was decreased to 1 sec where it remained for the rest of the experiment. The subjects adapted quickly to the short reinforcer durations; observation of the subjects via closed-circuit television revealed that they rarely missed an opportunity to drink when the valve was operated. However, because ducklings less than a week old consume so little food and water, response shaping with water reinforcement took one more day to complete than shaping with the imprinting stimulus.

On Days 6 to 14 the ducklings were run in regular 90-min daily sessions. Three ducklings were studied on FR schedules (FR-water group) and the other two ducklings were studied on FI schedules (FI-water group). On Days 6 and 7 posthatch these ducklings were exposed to the same sequences of FR and FI schedules as their counterparts studied with the imprinting stimulus. The highest value schedules, FR 30 and FI 60-sec, remained in effect throughout Days 8 to 14. The experiment was then terminated for all subjects except one from the FI-water group. This subject

was allowed to live in the chamber on a 24-hr basis over Days 15 to 18 with the FI 60-sec schedule continuously in effect.

The ducklings were deprived of food and water for 2 hr before the first "exposure" session on Day 2. Over Days 3 to 7 food and water in the home units were removed for increasingly longer periods. Over Days 7 to 14, access to food and water in the housing unit was permitted only during the first 90 min after the end of each daily session.

RESULTS

Mean response rates in daily sessions are shown in Figure 1, averaged across subjects in each group. In the initial sessions, when CRF and the lower value intermittent schedules were in effect, three of the four ducklings in the FI-imprinting group and three of the four ducklings in the FR-imprinting group responded at rates comparable to those maintained by the subjects afforded water reinforcement (<5 responses per min). The functions shown in Figure 1 for the FR-imprinting and FI-imprinting groups are based on the data from these six ducklings. The other two ducklings studied with the imprinting stimulus responded at very low overall rates (<2 re-

sponses per min) throughout the experiment.

Figure 1 shows that over Days 8 to 14, when the schedule parameters were kept at their highest values (FR 30 and FI 60-sec), overall rates of responding were either maintained at about their initial levels, or had increased, in all groups except FR-imprinting. The subjects in this group had virtually ceased responding by the end of the experiment.

By Days 10 to 12, characteristic FR and FI schedule control was evident in the cumulative records of all ducklings that responded for water reinforcement. Figure 2 shows a record of responding on FR 30 for a subject afforded water reinforcement. The record represents the entire session on Day 10.

The "break-run" pattern typical of fixed-ratio performance in adult animals with food or water as reinforcement is clear in this record. Following reinforcement, a brief period of no responding (the "break" or "postreinforcement pause") usually occurred. Once responding resumed, however, the schedule was met with a sustained burst of rapid responding (the "run") with little variability in rate within the burst. In the latter half of the session, some larger postreinforcement pauses occurred, apparently as a result of satiation (Sidman & Stebbins, 1954).

The scallop effect typical of FI performance was evident in the cumulative records of the FI-water group by Day 10 posthatch. In most of the reinforcement cycles, responding tended to occur at relatively low rates immediately after reinforcement, but as the end of the fixed interval approached, responding accelerated to a relatively high terminal rate.

Prior research with conventional reinforcers has shown that if extended training is given on a fixed-interval schedule, the smooth scallop pattern is gradually replaced by a pattern with abrupt transitions similar to those which appear in FR schedules (Ferster & Skinner, 1957, p. 158; Schneider, 1969). This effect was observed in the present study in the records from the duckling that was allowed to live in the chamber after Day 14 with the FI 60-sec schedule continuously in effect. Figure 3 shows the development of terminal fixed-interval performance by this subject.

In the records of the ducklings that responded for presentation of the imprinting object there was no indication that the FR break-run pattern or the FI scallop pattern had even

Fig. 1. Mean rates of pole-peck responding in daily sessions for each experimental group in Experiment 1. For ducklings in the FR-water and FI-water groups, responding was maintained in fixed-ratio and fixed-interval schedules, respectively, with water reinforcement. Presentation of an imprinting stimulus served as reinforcement for the FR-imprinting and FI-imprinting groups. The data from two subjects, one from each of the imprinting groups, were not included in the calculation of the averages shown here.

Fig. 2. Cumulative record of an entire session for a subject trained with water reinforcement on fixed-ratio schedules in Experiment 1. Each response stepped the pen in an upward direction, and downward deflections of the pen indicated reinforcement delivery. While reinforcement was being delivered, responses did not step the pen and movement of the paper was stopped.

started to develop. Instead, the response patterns under both FR and FI schedules with reinforcement by the imprinting stimulus could best be described as highly erratic. Figure 4 shows the Day 10 record of the subject that exhibited the highest response rates in

the FR-imprinting group. As is evident in the record, responding on the FR schedule occasionally occurred in very rapid bursts of up to 25 or 30 responses; however, the occurrence of these bursts was apparently not a product of the FR schedule, since similar bursts also

Fig. 3. Cumulative records for a subject given extended training on FI 60-sec with water reinforcement in Experiment 1. The records show the pattern of responding when the FI 60-sec schedule was first introduced (Cycles 1 to 17), at an intermediate stage of training (Cycles 451 to 474), and at the end of training (Cycles 2274 to 2290).

were evident in the records of the ducklings that were only exposed to FI schedules following initial training on CRF.

It is not surprising that the break-run pattern was not exhibited by ducklings in the FR-imprinting group because these subjects gradually stopped responding over the course of training (see Figure 1) and hence there was little opportunity for schedule control to develop. Whereas ducklings in the FR-water group had each obtained approximately 150 to 300 reinforcers on FR 30 before the break-run pattern was clear, the ducklings in the FR-imprinting group had each obtained fewer than 100 reinforcers on FR 30 during the entire experiment.

The absence of typical FI scallop patterns with the imprinting stimulus, however, cannot be so readily dismissed as due to insufficient practice. With water as a reinforcer typical FI performance was evident in the cumulative records after approximately 200 reinforcement cycles on FR 60-sec. In contrast, the three ducklings in the FI-imprinting group with the highest overall response rates had obtained 488, 513, and 543 reinforcers on FI 60-sec by

Fig. 4. Cumulative record of an entire session for a subject trained on fixed-ratio schedules with reinforcement by presentation of an imprinting stimulus in Experiment 1.

the end of the experiment, yet no clear scallop effect was exhibited by these subjects. These observations are substantiated by the analysis described below.

Samples of records from an operations recorder were used to provide a quantitative measure of the fixed-interval scallop effect. Each sample consisted of a block of 50 consecutive reinforcement cycles. Each of the 60-sec fixed-interval cycles was divided into six successive 10-sec periods, and the mean rate of responding in the successive 10-sec periods

Fig. 5. The development of fixed-interval "scallop" effects as indicated by the rate of responding as a function of time within the fixed interval, for subjects trained on FI 60-sec in Experiment 1. Each function shows the response rates of an individual subject, averaged across 50 consecutive fixed intervals (reinforcement cycles).

was calculated for each block of 50 cycles. An increasing function would indicate a scallop effect, i.e., an acceleration of responding over the course of the fixed interval. Figure 5 shows the functions obtained for individual ducklings when the FI 60-sec schedule was introduced (Cycles 1 to 50), and after 200 reinforcers on the FI 60-sec schedule had been delivered (Cycles 201 to 250). The figure also shows the function based on the last 50 cycles completed by each duckling in the FI-imprinting group. When first exposed to the FI 60-sec schedule, the two ducklings in the FI-water group responded at an essentially constant rate over the course of the fixed interval, as indicated by the relatively flat functions for Cycles 1 to 50. After 200 reinforcement cycles, the acceleration of responding characteristic of FI performance was well established in these ducklings. In contrast, no comparable effects were exhibited by the ducklings in the FI-imprinting group, despite the fact that by the end of the experiment these ducklings had obtained more than twice as many reinforcers as were needed to generate the scallop pattern with water reinforcement. Duckling S5 exhibited some tendency to respond at increasing rates over the course of the fixed interval, but this effect was apparently not generated by the FI schedule requirement, since the acceleration was most pronounced when the FI 60-sec schedule was first introduced.

Not only did a scallop effect fail to develop in the FI-imprinting condition, there were also no other obvious changes in the pattern of responding over the course of the experiment. Figure 6 shows the initial and final segments of the cumulative record of responding on FI 60-sec for Duckling S6, the subject which had the most exposure to this schedule with the imprinting stimulus as the reinforcer. Whereas the overall rate of responding was greater during the final reinforcement cycles than during the initial cycles for this subject, the pattern of responding still had the same erratic character.

DISCUSSION

Perhaps the simplest account of the results of Experiment 1 would be that under the conditions of this experiment the imprinting object was merely a quantitatively weaker reinforcer than water. That is, the reinforcement provided by the imprinting object was not

strong enough to maintain responding on FI 30 or to produce a scallop pattern on FI 60-sec. This hypothesis implies that it might be possible to obtain better schedule control with an imprinting stimulus under more favorable conditions. Experiments 2 to 4 employed a variety of procedures to investigate this possibility.

EXPERIMENT 2

Experiment 2 represented an attempt to maximize the likelihood that a fixed-interval scallop effect might develop with reinforcement provided by an imprinting stimulus. The procedure simply involved giving ducklings prolonged exposure to FI 30-sec until their response rates declined to minimal levels. Such a decline has been observed to occur with extended training on CRF for presentation of an imprinting stimulus as the subjects mature (Hoffman & Kozma, 1967). The smaller schedule parameter (30-sec, rather than 60-sec as in Experiment 1) was selected so that more rein-

Fig. 6. Cumulative records of a subject trained on FI schedules with reinforcement by the imprinting stimulus in Experiment 1. The top records show the response pattern when the FI 60-sec schedule was first introduced, and the bottom records show the pattern after more than 500 reinforcer cycles on FI 60-sec had been completed.

forcement cycles could be completed within a given period of training.

METHOD

Subjects

The subjects were three newly hatched Khaki Campbell ducklings.

Apparatus

The apparatus used to study reinforcement by the imprinting stimulus in Experiment 1 was also used in Experiment 2.

Procedure

Over Days 1 to 4 posthatch the ducklings in this study were given the same imprinting and response shaping procedures as subjects trained with the imprinting stimulus in Experiment 1. Regular 90-min daily sessions were initiated on Day 5 posthatch. Within the first half of the session on Day 5, the schedule was changed from CRF to FI 10-sec to FI 20-sec and finally to FI 30-sec, which remained in effect throughout the remainder of the experiment.

Two of the ducklings (P46 and P52) were run until fewer than 30 reinforcements were obtained in each of three consecutive sessions. Duckling P46 reached this criterion on Day 16, and Duckling P52 on Day 21. The third duck-

ling, P49, was still responding at a relatively high rate by the end of the session on Day 26, and the daily 90-min sessions were discontinued at this point. Over the next two days this duckling was run on a 24-hr basis with the FI 30-sec schedule continuously in effect and with food and water available from cups placed along the back wall of the subject compartment. The experiment was terminated for this duckling when it had obtained a total of 3,000 reinforcements on FI 30-sec, including those obtained in the daily 90-min sessions.

RESULTS AND DISCUSSION

Rate of responding as a function of time within the fixed interval is depicted in Figure 7. For each subject the functions are shown for the first block of 200 cycles that occurred on the FI 30-sec schedule, for the final block of cycles, and for an intermediate block. For Duckling P49 the intermediate block represents the last 200 cycles completed before the regular 90-min sessions were discontinued and training was conducted on a 24-hr basis.

The only effect evident in Figure 7 that was consistent across all three subjects was a decline in the overall rate of responding over the course of the experiment. In two subjects, P46 and P52, there was a suggestion of an effect on the response patterns that could have been

Fig. 7. Rate of responding as a function of time within the fixed interval for subjects trained on FI 30-sec with reinforcement by the imprinting stimulus in Experiment 2. The functions show the response rates of individual subjects, averaged across 200 consecutive fixed intervals, when the FI 30-sec schedule was first introduced (Cycles 1 to 200) and at later stages of training.

a product of the FI contingency. When these ducklings were first put on the FI 30-sec schedule (Cycles 1 to 200), they exhibited the opposite of a scallop effect, i.e., response rate decreased over the fixed interval. Since flatter functions were obtained later in training, it might be argued that the schedule requirement eliminated the "reversed scallop." Such an explanation is gratuitous, however, since the disintegration of any response patterns present at the beginning of training might simply be a reflection of the general decline in response strength that occurred over the course of the experiment. In any case, there was no clear evidence that a typical FI scallop effect emerged over the course of training in any subject.

It should be noted that Duckling P49 was housed in the chamber with food and water continuously available during Reinforcement Cycles 1751 to 3000. Under these circumstances the duckling had the opportunity to "mediate" a scallop effect by learning to eat or drink instead of peck near the beginning of the fixed interval; yet, as suggested by the relatively flat function for Cycles 2800 to 3000, such an outcome was not very pronounced if it occurred at all.

Figure 8 shows the initial and final segments of the cumulative record of the FI 30-sec performance of Duckling P49. The only striking difference in performance at the beginning and end of training apparent in Figure 8 is that periods of nonresponding were much longer

at the end of training. In both segments it is evident that the duckling often emitted rapid bursts of 10 to 20 responses similar to those of the ducklings that responded for the imprinting stimulus in Experiment 1 (see Figures 4 and 6). As is evident in the bottom segment of Figure 8, Duckling P49 still initiated many of these bursts near the beginning of the fixed interval despite prolonged prior exposure to the schedule.

EXPERIMENT 3

Experiment 3 was conducted to assess the possibility that the breakdown of responding for the imprinting stimulus on FR 30 in Experiment 1 might have resulted from "ratio strain," i.e., from introducing the higher value FR schedules too abruptly. Thus, in Experiment 3 responding reinforced by the imprinting stimulus was studied using a series of FR schedules in which the response requirement was increased very gradually.

METHOD

Subjects

Six newly hatched ducklings served.

Apparatus

The apparatus used with the imprinting stimulus in Experiment 1 was employed.

Procedure

Imprinting and response shaping procedures were the same as in the imprinting reinforce-

Fig. 8. Sample cumulative records from the beginning and end of training on FI 30-sec with reinforcement by the imprinting stimulus for a subject in Experiment 2. The interruption in the record from the beginning of training (Cycles 1 to 67) represents a break between sessions.

ment condition of Experiment 1 and were completed by Day 4 posthatch. From Day 5 until the end of the experiment, all ducklings were run in 90-min daily sessions. CRF was in effect at the beginning of the session on Day 5. After 50 reinforcements on CRF, the schedule requirement was increased to FR 2. After the subject obtained 25 reinforcements on FR 2, the experimenter checked the operations recorder. If, out of the last eight ratio "runs" (i.e., during Reinforcement Cycles 18 to 25 on FR 2), not more than three of them were "broken," then the schedule was raised to FR 3. A run was considered to be broken if the two responses were separated by more than 2.5 sec. (The time between reinforcement and the first response was not considered.) If more than three of the eight runs were broken, then the duckling was allowed an additional 25 reinforcers on FR 2. At the end of this block of cycles, the record was checked in the same manner as before. If the criterion was again not met, then the experimenter checked the record after another 25 cycles were completed, and so on. A similar criterion was used to determine whether a duckling currently responding on a fixed ratio of 3 or greater would be moved to a higher ratio. That is, the ratio was considered to be broken if any two consecutive responses within the run were spaced by more than 2.5 sec.

It was intended that the fixed-ratio requirement would be increased according to the following sequence: 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 23, 26, 30. However, if a duckling remained on a given fixed ratio for three consecutive sessions (because of failure to meet the criterion), the duckling was no longer run.

RESULTS AND DISCUSSION

One duckling (P32) in the present experiment reached FR 20 before failing to meet criterion in three consecutive sessions. The highest ratios reached by the other five ducklings before responding deteriorated ranged from 4 to 19. In the cumulative records of Duckling P32, however, a characteristic FR break-run pattern was sometimes exhibited. The pattern was most clear in the first two sessions after the FR 20 schedule was introduced (Days 14 and 15 posthatch), despite the fact that during these sessions the duckling's overall rate of responding was low (<3 responses per min). Figure 9 shows a segment

Fig. 9. Cumulative records of responding on FR schedules for a subject trained with water reinforcement in Experiment 1 (Duckling W3) and for a subject trained with the imprinting stimulus in Experiment 3 (Duckling 32).

of the record from Day 15 for Duckling P32, along with a segment of a record from a subject in the FR-water group of Experiment 1. The latter segment was obtained at the end of a session, when overall rate of responding was at a comparably low level (presumably because of satiation). In both records the low overall rate is entirely attributable to long postreinforcement pauses.

Duckling P32 was allowed two more sessions on the FR 20 schedule. In these sessions the pattern shown in Figure 9 was not consistently maintained.

EXPERIMENT 4

Experiment 4 sought to determine whether a stable break-run pattern might be engendered if the strength of the imprinting object as a reinforcer was somehow enhanced. One procedure that has been found to enhance the effectiveness of other reinforcers is the use of a brief stimulus that precedes the onset of the reinforcing event. For example, signaled food presentation is preferred over unsignaled food presentation (Brown, 1968), and reinforcing brain stimulation has been found to maintain characteristic performances on high-value schedules when each response-contingent train of stimulation is preceded by a brief light (Cantor, 1971). In Experiment 4, FR responding for the imprinting stimulus was studied using training procedures similar to those employed in Experiment 3, except that each presentation of the imprinting stimulus was preceded by a brief visual stimulus.

METHOD

Subjects

Five newly hatched ducklings served.

Apparatus

The apparatus used to study reinforcement by the imprinting stimulus in Experiment 1 was again used in Experiment 4.

Procedure

On Days 1 and 2 posthatch imprinting sessions were conducted as in Experiment 1. On Days 3 and 4 the ducklings were trained to peck the pole by the shaping method. Whereas in Experiments 1 to 3 the experimenter delivered a brief (.5 sec) presentation of the imprinting object when the duckling's movement approximated a pole peck, in this experiment the experimenter delivered a brief (.5 sec) illumination of the pole, which in turn was followed by a brief (.5 sec) presentation of the imprinting object. When the duckling actually pecked the pole, switch closure produced a 1-sec illumination of the pole followed by a

10-sec presentation of the imprinting stimulus. The onset of the presentation of the imprinting stimulus was simultaneous with the offset of the pole light. Responses that occurred during the pole light or during presentation of the imprinting stimulus had no programmed consequences.

Daily 90-min sessions were initiated on Day 5. Experiment 4 employed the same series of progressive FR schedules and the same criterion for determining when a ratio requirement would be increased as in Experiment 3.

Unlike Experiment 3, in which no duckling reached a ratio requirement higher than 20 before responding deteriorated, in the present experiment three subjects reached FR 30. Of these three ducklings, the two which exhibited higher overall response rates (P47 and P48) were given additional training on FR 30 in daily 90-min sessions until Day 23 posthatch.

RESULTS AND DISCUSSION

Higher ratio values were reached on the series of progressive FR schedules in Experi-

Fig. 10. Rates of responding in daily sessions on FR schedules for two subjects trained with reinforcement by signaled presentation of the imprinting stimulus in Experiment 4 (Ducklings P47 and P48) and for a subject trained with unsignaled water reinforcement in Experiment 1.

ment 4, when reinforcement was signaled (range = 10 to 30, median = 30), than in Experiment 3, when reinforcement was not signaled (range = 4 to 20, median = 7.5). A Mann-Whitney U-test revealed that the difference between experiments was statistically reliable ($U = 2.5$, $p < .05$).

Two of the ducklings in Experiment 4, P47 and P48, exhibited overall response rates comparable to the rates maintained on FR schedules by water reinforcement in Experiment 1. Figure 10 shows the individual rates for these ducklings in each 90-min session. The figure also includes the daily rates from Experiment 1 of Duckling W3, the subject that exhibited the lowest overall rates in the FR-water condition. The high variability in overall response rates evident in the functions of P47 and P48 was characteristic of all subjects that responded for the imprinting stimulus in the

present investigation. In contrast, the overall response rates of Duckling W3 (see Figure 10) and the other subjects that responded for water were relatively stable from session to session.

Figure 11 shows a segment of the cumulative record of Duckling P47 (the subject with the highest overall response rates in Experiment 4) from near the end of the experiment (Day 22), along with the final excursion of the pen for Duckling W3 (Day 14). Prior to the time of these records Duckling W3 had obtained approximately 110 reinforcers on FRs increasing from 5 to 25 and 400 reinforcers on FR 30, whereas Duckling P47 had obtained approximately 1000 reinforcers on FRs 2 to 26 and 750 reinforcers on FR 30. Despite the fact that P47 responded at higher levels and obtained many more reinforcers on FR schedules than W3, there was little indication of an FR break-

Fig. 11. Cumulative records of responding on FR 30 for a subject trained with unsignaled water reinforcement in Experiment 1 (top record) and for a subject trained with signaled presentation of the imprinting stimulus in Experiment 4.

run pattern in the records of P47, although typical FR performance was quite clear in the records of W3.

The only aspect of the response pattern of Duckling P47 that was at all characteristic of FR performance with conventional reinforcement was the occasional occurrence of rapid, sustained bursts of responses. Such rapid responding is evident in the middle excursion of the pen in the record of P47 in Figure 11. However, the most striking feature of characteristic FR performance—the biphasic pattern in which responding occurs at its maximal or near maximal rate or not at all—was absent in the records of Duckling P47 and the other subjects of Experiment 4. Throughout training there were periods of sporadic responding, as indicated by the occasional “grain” in the records. Long periods of no responding (e.g., 30 sec or more) appeared not only as pauses after reinforcement but also as interruptions of partly completed runs.

In summary, the findings of Experiments 2, 3, and 4 cast doubt upon an explanation of the atypical schedule performances generated by the imprinting stimulus solely in terms of the overall weakness of the stimulus as a reinforcer. In Experiments 5 and 6, two other explanations were examined.

EXPERIMENT 5

The purpose of Experiment 5 was to compare the extinction of behavior established by the imprinting stimulus with the extinction of behavior established by water reinforcement. This comparison was of interest because atypical schedule control by another unconventional reinforcer—brain stimulation—seems to be related to rapid extinction. That is, under some circumstances responding established by brain stimulation extinguishes so rapidly that when a lean reinforcement schedule is introduced, responding ceases before the next reinforcer is scheduled to be delivered (Gallistel, 1973). Furthermore, it seemed possible that the atypical schedule control with the imprinting stimulus might be attributable to insufficient resistance to extinction. Hence, Experiment 5 sought to determine whether responding established by the imprinting stimulus does in fact extinguish more rapidly than responding established by water reinforcement.

METHOD

Subjects

Twelve newly hatched ducklings served. Five of these were assigned to be studied with water reinforcement, the other seven with the imprinting stimulus.

Apparatus

The apparatus used to provide reinforcement by the imprinting stimulus in Experiment 1 and the apparatus adapted for water reinforcement in Experiment 1 were both employed in Experiment 5.

Procedure

The procedures used for establishing the pole peck response in Experiment 5 were the same as the procedures used in Experiment 1, except for one change. Whereas in Experiment 1, for the water reinforcement birds, the light on the pole was used as a visual signal to indicate that water was flowing, in Experiment 5 the pole was never illuminated. Another reinforcement signal was still available since the valve which controlled water delivery produced an audible click when operated.

By Day 4 the response was shaped in all subjects. Over Days 5 to 8 all subjects were given daily sessions with CRF in effect throughout. Each session was terminated after 100 reinforcements were delivered. In this respect Experiment 5 differed from Experiments 1 to 4, in which session length was fixed at 90 min. By terminating each session after the delivery of a fixed number of reinforcements, it was ensured that all subjects would have accumulated the same number of reinforced responses before extinction was initiated.

On Day 9 the session was begun with CRF in effect, but after 20 reinforcements were delivered extinction was initiated. The session was terminated after 90 min of extinction. During extinction the number of responses that occurred in each successive 18-min period was recorded. On Day 10 another 90-min session of extinction was conducted. This session was started with extinction in effect, but after 90 min CRF was resumed. If the subject did not resume responding within 5 min after the CRF contingency was reinstated, shaping was used to reinstate pecking. Experiment 5 was terminated after 100 reinforcers were obtained on CRF on Day 10.

RESULTS AND DISCUSSION

In the data analysis of Experiment 5, each 90-min extinction session was divided into five 18-min periods, and each subject's response rates were calculated separately for each period. Figure 12 shows the mean response rates for the two groups of subjects during the last session of CRF before extinction, during successive 18-min extinction periods, and during the postextinction session of reconditioning on CRF. The group extinction functions indicate that, if anything, responding established with the imprinting stimulus extinguished more slowly than responding established with water. The results imply that the atypical schedule performances generated by the imprinting stimulus in Experiments 1 to 4 cannot be attributed to insufficient resistance to extinction.

EXPERIMENT 6

Experiment 6 was designed to determine whether the atypical response patterns generated by the imprinting stimulus on ratio and interval schedules could be attributed to a lack of control by discriminative stimuli. A number of investigations have suggested that control of response patterns by fixed-ratio and fixed-interval schedules relies on attention to a number of implicit discriminative stimuli, such as temporal and response-produced cues (Ferster & Skinner, 1957; Kello, 1972; Neu-

ringer & Schneider, 1968). For example, the postreinforcement pause may reflect inhibitory control by a temporal cue—time since reinforcement. Thus, it is possible that the erratic performances engendered by the imprinting stimulus on fixed-ratio and fixed-interval schedules are due to a more general failure of the subjects to attend to discriminative stimuli. If this hypothesis is correct, then the acquisition of discriminative control by the stimulus components of a multiple schedule should proceed relatively slowly, if at all, with the imprinting stimulus as the reinforcer.

METHOD

Subjects

The ducklings that served as subjects in Experiment 5 were used again in Experiment 6.

Apparatus

The apparatus used for reinforcement by the imprinting stimulus and the apparatus adapted for water reinforcement were again employed in Experiment 6.

Procedure

By the end of Experiment 5, all of the subjects had been exposed to extinction and reconditioning procedures. Experiment 6 was begun on Day 11. Over Days 11 to 13 all subjects were trained on a two-component multiple schedule with a fixed-interval 15-sec schedule as one component and extinction as the other component, i.e., mult FI 15-sec EXT. Illumination of the pole light served as one discriminative stimulus, and the absence of the illumination served as the other discriminative stimulus. For four of the subjects trained with water and three of the subjects trained with the imprinting stimulus, the illuminated pole was S^D (the stimulus correlated with reinforcement) and the dark pole was S^Δ (the stimulus correlated with extinction). For the remaining subjects (three trained with the imprinting stimulus and two trained with water), the lighted pole was S^Δ and the dark pole was S^D . S^D and S^Δ periods were always 1 min in duration and were presented in strict alternation. Whenever reinforcement occurred during S^D , the 1-min timer was stopped at the onset of reinforcement delivery, and it resumed timing after reinforcement termination. Responses that occurred during reinforcement

Fig. 12. Mean rates of responding in Experiment 5 during continuous reinforcement (CRF) and extinction for a group of ducklings trained with reinforcement by the imprinting stimulus and for a group trained with water reinforcement. Response rates are shown for the last session of CRF prior to extinction, for successive 18-min periods of extinction, and for the session of reconditioning on CRF. The interruption in the extinction function represents the break between the two 90-min extinction sessions.

delivery were not counted. Each session was terminated after the delivery of 100 reinforcers.

For all but two of the subjects, the experiment was terminated after the completion of three sessions of discriminative training. The other two subjects, both trained with the imprinting stimulus, were kept in the chamber for approximately 48 hr after the completion of the third daily session. The mult FI 15-sec EXT schedule was continuously in effect during this time, and food and water were available from cups in the chamber. Over this 48-hr period, one subject (S71) obtained approximately 500 reinforcers on the schedule, while the other subject (S75) obtained approximately 600.

RESULTS AND DISCUSSION

For each individual subject the following index of discriminative performance was calculated:

$$\text{Discrimination index} = \frac{S^D \text{ rate}}{S^D \text{ rate} + S^A \text{ rate}}$$

The value of this index is .5 when the subject responds equally often in S^D and S^A , and it reaches a maximum of 1.0 when discriminative control is perfect. The top panel of Figure 13 shows the mean indices for each of the four subgroups of birds (2 reinforcers $\times$ 2 S^D/S^A assignments) over the three sessions of discriminative training. In order to examine within-session changes in discriminative performance, the total duration of each session was divided into three equal periods, and the index was computed separately for each period.

As is evident in the top panel of Figure 13, the birds given water reinforcement acquired the discrimination quite readily, reaching near perfect performance by the middle of the third session. In contrast, for the birds trained with the imprinting stimulus, the control acquired by the discriminative stimuli was weak at best. In fact, the subgroup trained with the imprinting stimulus and with the lighted pole as S^D exhibited no improvement at all over the three sessions. The mean index for this subgroup was above .5 throughout training, but this performance probably reflects an unconditioned initial preference for the lighted pole. This suggestion is consistent with the fact that the birds trained with the imprinting stimulus and with the light as S^A produced ratios under

.5 at the start of training. For these birds the discriminative training seems to have eliminated the initial preference for the lighted pole (S^A).

The functions for the individual subjects were consistent with the group averages. Four of the individual functions, one from each subgroup, are shown in the bottom panel of Figure 13. The two subjects chosen to represent the imprinting stimulus subgroups were those that were given 48-hr additional training. The data from this extended training were analyzed by computing the index for each successive period in which 100 reinforcers were delivered. Thus, the abscissa for the bottom panel, which shows the results of the extended training, differs from the abscissa in the top panel, which shows only the results of the first three sessions. As is evident in the bottom panel, the additional training given to S71 and S75 did not improve appreciably the performance of these subjects.

It will be recalled that a rather curious phenomenon was observed in the FR records of

Fig. 13. Discriminative performance of subjects trained on a mult FI 15-sec EXT schedule in Experiment 6, with a light on the response pole serving either as the signal for FI 15-sec (S^D groups) or as the signal for extinction (S^A groups). The top panel shows the mean discrimination index for groups of subjects trained with either the imprinting stimulus or water as the reinforcer, over successive periods of training. The interruptions in these group functions represent breaks between sessions. The bottom panel shows the discrimination index for individual subjects, averaged within blocks of 100 reinforcement cycles.

Fig. 14. Cumulative records of discriminative performance on a mult FI 15-sec EXT schedule in Experiment 6, for a subject trained with water reinforcement and for two subjects trained with the imprinting stimulus. In these records the pen was deflected upward during FI 15-sec periods and downward during extinction periods. During reinforcement delivery on FI 15-sec movement of the paper was stopped and responses did not step the pen.

subjects trained with the imprinting stimulus in Experiments 3 and 4. In those experiments there was considerable within-session variability not only in the overall response rates but also in the response patterns. That is, at times a subject would respond in a more-or-less typical fixed-ratio pattern, but at other times the same subject would respond in a more erratic manner. In the records from Experiment 6, there was some suggestion of an analogous phenomenon. That is, while pecking for the imprinting stimulus on the multiple schedule,

a subject would largely restrict its responses to S^D over some periods of time, but at other times would respond at nearly equal frequencies in both S^D and S^A . This variability is documented in Figure 14, which includes sample records from the two subjects given additional training with the imprinting stimulus (S75 and S71) and from a subject trained with water (W22). For each subject, the pair of segments shown in the figure represents one continuous part of the record. Virtually perfect discriminative control is evident in the segments for

W22. A high level of discriminative control also appears to be evident in the first segment for S71 and in the second segment for S75. However, the adjacent segments obtained from these same subjects seem to indicate a complete *lack* of discriminative control.

In summary, these data suggest that there was considerable fluctuation over time in the degree to which subjects trained with the imprinting stimulus were under the control of the explicit discriminative cues used in Experiment 6. Thus, it is possible that the erratic performances generated by the imprinting stimulus on fixed-ratio and fixed-interval schedules in Experiments 1 to 4 were due to a fluctuation over time in the degree of discriminative control by implicit temporal and/or response-produced cues.

GENERAL DISCUSSION

The immature ducklings that served as subjects in the present investigation were clearly capable of characteristic FR, FI, and multiple schedule performances—in all respects the response patterns exhibited by every subject trained with water reinforcement resembled the patterns typically obtained with food or water reinforcement in adult animals of other species. In contrast, with reinforcement consisting of presentation of an imprinting object evidence of schedule control was meager. In only one subject trained on FR schedules with the imprinting stimulus was there a suggestion of typical FR performance (Duckling P32 of Experiment 3), but even here the break-run pattern engendered was not very stable. In some subjects trained on FR schedules with the imprinting stimulus, responding occasionally occurred in rapid sustained bouts, but at other times responding was more sporadic. In no subjects trained on FI schedules with the imprinting stimulus did a scallop pattern develop, and discriminative control on multiple schedules was inconsistent at best. In general, the responding engendered by the imprinting stimulus on all the schedules was very erratic.

The prior investigations of intermittent reinforcement by an imprinting stimulus (Eiserer et al., 1975; Peterson, 1960, 1962) did not analyze the response patterns in detail, but Peterson's reports do contain a cumulative record of responding on FR schedules. The

pattern of responding evident in this record (Peterson, 1960, Figure 2; 1962, Figure 2) bears a close resemblance to the response pattern observed on FR schedules with an imprinting stimulus in the present study. The record shows sustained bursts of relatively rapid responding separated by periods in which responding was more sporadic. Many of the runs of responses between reinforcers were interrupted, even near the end of training when about 700 prior reinforcers on FR 8 had been obtained. Although Peterson did report, in contrast to the present results, that strong discriminative control on a multiple schedule was achieved, he did not elaborate on the stability of the discriminative performance or on the amount of prior training needed to generate it.

The present findings are also consistent with what little information is available about operant responding on intermittent schedules with other reinforcers that could be considered as social surrogate objects. Thompson (1964) studied the FR performance of adult roosters in a three-key operant chamber. Responding on one key (the "social key") produced either the presentation of the rooster's own image in a mirror or the view of another rooster in an adjacent cage. Responding on a second key produced water, and on the third key, food. The authors noted that, although response patterns occurred on the food key, responses on the social key occurred in irregularly spaced short bursts, interspersed with periods of more characteristic ratio behavior. Reinforcement by brief presentation of a mirror has also been used in a study of FR performance in male Siamese fighting fish (Hogan, Kleist, & Hutchings, 1970). Again the response patterns were described as "highly irregular." Finally, the FR responding of young male chaffinches with reinforcement consisting of exposure to a recording of the song of an adult chaffinch was also characterized as "irregular" (Stevenson, 1967).

Prior research on the "priming" effects generated by an imprinting stimulus (Eiserer & Hoffman, 1973) has implied that this reinforcer might be functionally comparable to electrical brain stimulation. However, the present data point to a difference in schedule control exerted by an imprinting object versus brain stimulation reward. Poor schedule control in the context of intermittent reinforce-

ment by brain stimulation has meant a deficit in the capacity of this reinforcer to sustain responding at all, except on CRF and very low-value FR and FI schedules. In contrast, with reinforcement by an imprinting stimulus, a given schedule may "take control" in the sense that substantial overall *levels* of responding are sustained on the schedule over many sessions (i.e., on FR 30-sec in Experiment 4, FI 60-sec in Experiment 1, and FI 30-sec in Experiment 2) yet it may exert little or no control over the *pattern* in which the responding occurs.

It seems unlikely that the present data can be explained with reference to any simple hypothesis about the overall potency of the imprinting stimulus versus water as reinforcers. In order to do so, one would have to assume that the imprinting object was sufficiently potent to generate response rates as great as, or greater than, those maintained by water reinforcement, and yet was not strong enough to establish the temporal patterns of responding that rapidly developed with water. From such an assumption one would have expected that better schedule control over response patterns would have been obtained in Experiment 4, when the reinforcement signal was used, than in Experiment 3, when the signal was not used. However, the one duckling trained on FR schedules which for some time exhibited a clear break-run pattern (P32) was a subject in Experiment 3. Finally, the stability on FR and FI response patterns over a broad range of deprivation/satiation conditions (Ferster & Skinner, 1957) casts doubt upon an interpretation of the present data solely in terms of a quantitative difference in overall reinforcer effectiveness.

It seems to be more appropriate to hypothesize that the poor schedule control generated by the imprinting stimulus is due to a lack of discriminative control rather than to a lack of reinforcing potency. Support for this hypothesis was obtained from Experiment 6, in which the discriminative stimulus of a multiple schedule did not consistently exert control over operant behavior reinforced by the imprinting stimulus, although these same stimuli did acquire strong control over behavior reinforced by water. This hypothesis also could account for the erratic performances generated by the imprinting stimulus on fixed-interval and fixed-ratio schedules, since on these sched-

ules there are stimuli such as temporal and response-produced cues which are not explicitly programmed by the experimenter but which may come to control various aspects of the response patterns (Ferster & Skinner, 1957; Kello, 1972; Neuringer & Schneider, 1968).

It is perhaps of special interest that in the present work the subjects that exhibited good control by FI and FR schedules (the ducklings whose responses were reinforced by water) were never without a surrogate object. For these birds a foam rubber ball (i.e., an imprinting stimulus) hung in their home units, and of equal importance, a similar ball hung next to the pole in the apparatus where water was employed as reinforcement. It seems possible that the consistent presence of such an object may permit a young bird to attend to cues that otherwise might go unnoticed. On the other hand, ducklings trained with a surrogate object as the reinforcer might, in the absence of the object, be so focused on regaining contact with it that discriminative control by other, more subtle forms of stimulation is minimized.

Although it is clear that an attentional effect of this sort can explain the relatively poor schedule performance of the imprinting birds, it is also clear that a final resolution of the issue is probably going to require a direct empirical analysis. In the meantime it seems appropriate to conclude that the present findings point to what may be a unique limiting factor in the behavioral control afforded when the presentation of a social stimulus is employed to reinforce the responses of a young developing organism.

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