SCHEDULE-INDUCED MIRROR RESPONDING IN THE PIGEON¹

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Two pigeons that were previously exposed to a multiple schedule of reinforcement in the presence of a stuffed and a live pigeon, and two of three naive pigeons, responded on a mirror during exposure to multiple fixed-ratio, fixed-ratio schedules of reinforcement for key pecking. Both the topography and temporal pattern of mirror responding were comparable to schedule-induced "attack" on live and stuffed targets. Rate of target responding was reduced when either the mirror was covered with paper or when the multiple schedule was removed. A reversal in the relationship between reinforcement schedules and discriminative stimuli demonstrated that mirror responding was controlled by the stimulus correlated with the higher fixed-ratio schedule. With one component of the multiple schedule held constant at fixed ratio 25 and the ratio requirement of the other component varying from 25 to 150, there was an inverted U-shaped relationship between rate of mirror responding and fixed-ratio schedule in the varied component. As in Flory's study (1969b) there was an inverted U-shaped relationship between target responding and inter-food intervals. The combined results of these studies suggest that the relationship between rate of target responding and reinforcement schedules is controlled primarily by the inter-food intervals resulting from the schedules.

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General Discussion

A number of experiments (*e.g.*, Flory, 1969a; Gentry, 1968) have reported the phenomenon of schedule-induced attack with the pigeon on fixed-ratio (FR) schedules of positive reinforcement. Specifically, this refers to the fact that if a pigeon's key pecks are reinforced on a relatively high fixed-ratio schedule (*e.g.*, 50 to 100)

in the presence of a target pigeon, the subject will often charge, peck, or pluck the feathers from the target during the post-reinforcement pause.

The two pigeons used in Experiment I of this study had previously been exposed to a multiple FR 25 FR 100 schedule of positive reinforcement in the presence of a taxidermically stuffed pigeon. Although one might have predicted (Flory, 1969a) that both pigeons would have responded on the stuffed pigeon after presentation of the stimulus correlated with the higher FR schedule, neither animal did so. However, when a live, restrained pigeon was substituted for the stuffed target on the same multiple schedule, both pigeons responded on the live target during the FR 100 component. In fact, responding on the live bird was so vigorous around the head and

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chest, it was impossible to maintain a constant, visual, pigeon target either within or across experimental sessions. To alleviate this problem a mirror was substituted for the live pigeon. Since mirror-image stimulation (Galup, 1968) differs considerably from stimulation by either a live or taxidermically stuffed pigeon in terms of tactile and visual feedback, the following experiments were conducted to determine if responding on a mirror during exposure to a multiple FR FR schedule of reinforcement is functionally comparable to the responding on live and stuffed pigeons reported in previous experiments. Experiment Ia examined the sequential relationship between a pigeon's key pecking and mirror responding on a procedure in which only key pecks were reinforced on multiple FR FR schedules ranging from FR 25 FR 25 to FR 25 FR 150.

EXPERIMENT I

GENERAL METHOD

Subjects

Two White Carneaux pigeons, from Palmetto Pigeon Plant, Sumter, South Carolina, were maintained at 80% (± 15 g) of their free-feeding body weights throughout Experiments Ia-Id. Both pigeons were approximately one-year old at the start of the experiment, and were housed in individual home cages under constant illumination. Both pigeons had experimental histories on a multiple FR 25 FR 100 schedule of reinforcement in the presence of live and taxidermically stuffed pigeons.

Apparatus

A 31.5 by 35.3 by 35.3 cm (12.6 by 14.1 by 14.1 in.) operant pigeon chamber with a Lehigh Valley Electronics, two-key intelligence panel was used in Experiments Ia to Id. Only the response key to the left of the grain hopper was operative. This key was transilluminated with either a green or white light and had a minimum force requirement for operation of 15 g as measured by a Jonard dynamometer. A 12.8 cm (5 in.) wide, 30.2 cm (12 in.) high and 0.23 cm thick mirror was suspended by two wires from a frame on the side wall closest to the response key. A microswitch was mounted at each corner of the mirror between the mirror and the frame, and a minimum force

requirement of 80 g was necessary to operate one of them. Closure of any one microswitch or the simultaneous closure of more than one was recorded as one mirror response. The distance between the edge of the mirror closest to the intelligence panel and the intelligence panel itself was 17 cm (6.8 in.). The centers of the response key and the food hopper were 11.4 cm (4.5 in.) and 17.8 cm (7 in.) respectively from the wall on which the mirror was mounted. With this arrangement, the pigeon neither brushed against the mirror nor was reflected in it while pecking the response key. Chamber illumination was provided by six, 1.6-W house-lights mounted on the roof of the chamber behind a ground glass shield. A wide-angle peephole was mounted on the chamber door, and a blower provided ventilation and masking noise. Experimental contingencies and recordings were scheduled by a system of relays, counters, and timers in an adjacent room.

EXPERIMENT Ia. RATE AND PATTERN OF MIRROR RESPONDING DURING MULTIPLE SCHEDULES

Procedure

Both pigeons were exposed to a multiple FR FR schedule of reinforcement that consisted of a fixed FR 25 schedule in the presence of a white keylight (S^D_1) and a varied FR schedule (FR 25 to FR 150) in the presence of a green keylight (S^D_2). Reinforcement was defined as 3-sec access to grain from the hopper. Throughout each session, one reinforcement in the presence of S^D_1 alternated with one reinforcement in the presence of S^D_2 . Daily sessions, which were generally conducted seven days/week, were terminated after either 60 reinforcements or 90 min, whichever occurred first. With the FR schedule in the fixed component held constant at 25, the FR schedule in the varied component (S^D_2) ranged from 25 to 150 in the following sequence: 100, 125, 150, 125, 100, 75, 50, 25, 50, 75, 100, 125, 150, 25, 150. From 11 to 14 sessions were given under each schedule.

RESULTS AND DISCUSSION

Both pigeons responded on the mirror during the multiple FR FR schedules. The sequential relationship between key and mirror responding in the S^D_2 component during the

Fig. 1. Cumulative number of key pecks plotted as a function of session time (minutes) for P-857 and P-8572. Each downward deflection of the pen corresponds to one mirror response. The recorder reset following the completion of each FR 75 component on the multiple FR 25 FR 75 reinforcement schedule.

second exposure to the FR 25 FR 75 schedule is shown for both pigeons in the cumulative records plotted in Figure 1. Cumulative number of key responses is plotted as a function of session time, with each downward deflection of the pen corresponding to one mirror response. The recorder reset after each FR 75 component was completed. Both records show that most mirror responses followed the presentation of the discriminative stimulus (SP_2) correlated with the higher FR schedule (FR 75). Cumulative records obtained for both pigeons during exposure to the other multiple FR FR schedules likewise demonstrated that mirror responses occurred almost exclusively after presentation of the discriminative stimulus correlated with the higher FR schedule. This relationship between key and mirror responding is comparable to that reported in other studies involving multiple reinforcement schedules (*e.g.*, Cole and Litchfield, 1969; Flory, 1969a) in which a live or taxidermically stuffed pigeon was used instead of a mirror.

Figures 2 and 3 plot, for P-857 and P-8572, respectively, overall rate of mirror responding (total responses/session length), local rate of mirror responding (total responses/cumulative post-reinforcement pause time³) and reinforcement rate (total reinforcements/session length)

as a function of successive sessions. The vertical dashed lines correspond to the changes in the FR schedule in the SP_2 component, and the horizontal dashed line within each block of sessions corresponds to the median rate during that block. With an increase in the FR requirement in the SP_2 component from 100 to 150, median overall and local rates of mirror responding decreased slightly for P-8572 (Sessions 1 to 35) and remained constant for P-857 (Sessions 1 to 37). Whereas a subsequent decrease in the FR schedule to 75 (Sessions 36 to 71 for P-8572 and Sessions 37 to 72 for P-857) produced increases in both measures of mirror responding, a further decrease to FR 25 resulted in decreases in both measures of responding to median rates of less than two mirror responses per minute. The subsequent increase in the FR schedule back to 100 for P-8572 and to 75 for P-857 was accompanied by increases in both measures of mirror responding, and a further increase to FR 150 produced decreases in those measures. Finally, re-exposure of both pigeons to an FR 25 and then to an FR 150 schedule was accompanied by a corresponding decrease and then increase in

³A post-reinforcement pause is defined as the time from the end of reinforcement to the first key peck.

mirror responding for P-857 and a decrease in mirror responding under both schedules for P-8572.

To facilitate a comparison of mirror responding across multiple FR FR schedules, the median of the median local and overall rates of mirror responding was examined during exposures to each multiple FR FR schedule. In Figure 4, median-median local rate of mirror responding is plotted as a function of the FR schedule in the S^{D_2} component. The bracket around each data point corresponds to the range in medians for that FR schedule. Although median local and overall (not shown in this figure) rates of mirror responding are positively correlated with FR schedules up to 75 and negatively correlated with FR sched-

ules greater than 75 for both pigeons, there was a wide range in median local and overall rates of mirror responding under some FR schedules. Reexamination of Figures 2 and 3 demonstrates that across exposures to multiple FR FR schedules, median local and overall rates of mirror responding were also correlated with median reinforcement rate. The relationship between local rate of mirror responding and reinforcement rate is summarized for both pigeons in the bottom panel of Figure 5. In this figure, median local rates of mirror responding that occurred during each exposure (11 to 14 sessions) to a multiple FR FR schedule are correlated, independently of the FR schedule, with the median of the mean interfood interval in S^{D_2} for those same sessions.

Fig. 2. Overall rate of mirror responding (total responses/session length), local rate of mirror responding (total responses/cumulative post-reinforcement pause time) and reinforcement rate (total reinforcements/session length) plotted as a function of successive sessions for P-857. The vertical dashed lines correspond to the changes in the FR schedule in the S^{D_2} component and the horizontal dashed line within each block of sessions corresponds to the median rate during that block. Different ordinal scales are used on the graphs in this figure. The absence of local rate data corresponds to sessions in which local rate of mirror responding was not available.

Fig. 3. Overall rate of mirror responding (total responses/session length), local rate of mirror responding (total responses/cumulative post-reinforcement pause time), and reinforcement rate (total reinforcements/session length) plotted as a function of successive sessions for P-8572. The vertical dashed lines correspond to the changes in the FR schedule in the S^{D_2} component and the horizontal dashed line within each block of sessions corresponds to the median rate during that block. Different ordinal scales are used on the graphs in this figure. The absence of local rate data corresponds to sessions in which local rate of mirror responding was not available.

This measure of inter-reinforcement time includes only the interfood intervals in S^{D_2} . In this figure, median mean inter-food intervals in S^{D_2} were plotted on a log scale to facilitate a comparison of the present results with those from an experiment by Flory (1969*b*). For both subjects, there was an inverted U-shaped relationship between median local rate of mirror responding and median mean inter-food interval in S^{D_2} with maximum rates of mirror responding occurring at inter-food intervals of 58 and 70 sec for P-857 and P-8572, respectively. Although not shown in Figure 5, there was a comparable inverted U-shaped relationship between median overall rates of mirror

responding and median mean inter-food intervals.

Both this inverted U-shaped relationship and the fact that inter-food intervals of 58 to 70 sec produced maximum rates of mirror responding are comparable to the results of Flory's (1969*b*) experiment (Figure 5, top panel). In that study, pigeons were given access to food at regular intervals in the presence of a taxidermically stuffed pigeon. Although overall response rate on the stuffed target was considerably lower than either overall or local rates of mirror responding in this study, an increase in the minimum inter-food interval from 15 sec to either 60 sec (Bird 2) or 120 sec

Fig. 4. The median of the median local rates of mirror responding (responses per minute) plotted as a function of FR schedules in the S_2^D component for both subjects. The bracket around each data point corresponds to the range in medians for that FR schedule.

Fig. 5. In the bottom panel, median local rate of mirror responding (responses per minute) during each exposure (11 to 14 sessions) to a multiple FR FR schedule is plotted as a function of the median-mean inter-food interval (seconds) in S_2^D , for those same sessions. The upper panel summarizes data reported by Flory (1969b). Overall rate of responding on a stuffed pigeon (responses per minute) is plotted as a function of minimum inter-food interval (seconds). In both the upper and lower panels, inter-food interval is plotted on a log scale. The ordinal scale used in the lower panel is one-tenth of that used in the upper panel.

(Bird 1) increased the rate of responding on the stuffed pigeon. As was the case in the present study, a further increase in the inter-food interval in Flory's study decreased the rate of responding on the stuffed pigeon.

Informal observations of the pigeons over the course of Experiment Ia indicated that approximately 90% of the mirror responses resulted from the pigeon pecking the mirror while standing in front of it. The remaining mirror responses were also pecks, but occurred in a burst immediately after the pigeon charged the mirror. In this respect, the response topography of mirror responding was similar to that reported for pigeons in extinction-induced attack (e.g., Azrin, Hutchinson, and Hake, 1966) and schedule-induced attack (e.g., Flory, 1969a) studies using live and stuffed pigeon targets.

In summary, the combined results of the two experiments suggest that there is an inverted U-shaped relationship between responding on a pigeon target and inter-food intervals with maximum responding occurring at intervals of approximately 1 to 2 min. The results of another experiment (Knutson, 1970) in which pigeons were exposed to a multiple FR 1 EXT FR (N) EXT schedule in the presence of a live, restrained pigeon are related to this finding. As the FR schedule in the FR(N) component was increased from 1 to 120, there was a corresponding increase in the number of responses on the target animal/session during the FR(N) component for four of the five subjects. For the fifth subject, however, an increase in the FR schedule above 60 decreased the number of target responses/session. The results for that subject, together with the results from the Flory study and the present one suggest that if the FR schedule in Knutson's experiment had been increased to higher values for the other four pigeons, the rate of target responding would have decreased.

EXPERIMENT Ib. CONTROL OF MIRROR RESPONDING AND KEY PECKING BY MIRROR IMAGE STIMULATION

In Experiment Ia, pigeons that were exposed to a multiple FR FR schedule in the presence of a mirror, responded on that mirror during the stimulus correlated with the higher FR schedule. To determine if mirror

responding in that situation was controlled by the mirror-image stimulation, the two pigeons used in that experiment were exposed to a series of sessions on a multiple FR 25 FR 150 schedule in which the mirror was alternately covered and uncovered.

Procedure

Both pigeons were exposed to 30 sessions on a multiple FR 25 FR 150 schedule in which the mirror was alternately uncovered and covered with a piece of brown construction paper over successive blocks of five sessions. This paper was similar in color to the wood on which the mirror was mounted. In both the covered and uncovered conditions, the minimum force required to operate a mirror microswitch was approximately 80 g.

RESULTS AND DISCUSSION

For both pigeons, the number of mirror microswitch closures per minute was less when the mirror was covered with paper than when it was uncovered. For those sessions in which the mirror was uncovered, the mean overall

Fig. 6. Median of reinforcement rates (reinforcements per minute) on a multiple FR 25 FR 150 schedule plotted for blocks of five sessions with the mirror alternately covered and uncovered.

rates (responses/minute) of microswitch closures were 6.8 (range across sessions of 3.05 to 11.87) for P-857 and 0.80 (range across sessions of 0.28 to 1.69) for P-8572. With the mirror covered, the rates decreased to 0.03 (range across sessions of 0.0 to 0.14) for P-857 and 0.04 (range across sessions of 0.01 to 0.09) for P-8572. In addition to controlling response rate on the mirror, mirror-image stimulation also controlled reinforcement rate on the multiple FR FR schedule. For both pigeons (Figure 6), median reinforcement rate was consistently lower for those blocks of sessions in which the mirror was uncovered than for those in which it was covered. The fact that mirror-image stimulation "strained" key pecking on the multiple FR FR schedule is similar to Knutson's observation (1970) that a pigeon's key pecking on a multiple schedule is reduced by the presentation of another live pigeon into the experimental chamber. As was the effect of covering the mirror in this study, removal of the live pigeon from the experimental chamber in Knutson's study resulted in a return to the previously high rates of key pecking.

EXPERIMENT 1c. CONTROL OF MIRROR RESPONDING BY DISCRIMINATIVE STIMULI DURING MULTIPLE SCHEDULES

Experiment 1b demonstrated that mirror responding that occurred during exposure to a multiple FR FR reinforcement schedule was controlled by the mirror-image stimulation. The next experiment determined if the mirror responding that occurred predominantly during the higher FR component of the multiple FR FR schedule was also controlled by the discriminative stimulus correlated with that component.

Procedure

Pigeons P-857 and P-8572 were exposed to 20 and 30 sessions, respectively, on a multiple FR 25 FR 100 schedule of reinforcement in the presence of the mirror. During the first 10 sessions, a white keylight was correlated with an FR 25 schedule and a green keylight was correlated with an FR 100 schedule for both birds. During the final 10 sessions for P-857 and 20 sessions for P-8572, the relationship between keylight color and FR schedule was reversed with a white keylight correlated

with the FR 100 schedule and a green keylight correlated with the FR 25 schedule.

RESULTS AND DISCUSSION

The upper portion of Figure 7 includes the cumulative records for P-8572 during the final session (Session 10) in which the white keylight was correlated with the FR 25 schedule and the green keylight was correlated with the FR 100 schedule. The bottom portion of this figure includes the cumulative records from the first, second, and fourth sessions (Sessions 11, 12, and 14) following the reversal in relationship between keylight color and FR schedule. In each record, the cumulative number of key pecks is plotted as a function of session time, with each downward deflection of the pen corresponding to one mirror response. The recorder reset after each FR 100 component was completed. During the last five sessions preceding the reversal in relationship (Sessions 6 to 10) mean overall rates of mirror responding were 4.6 and 5.3 responses per minute for P-8572 and P-857, respectively. During those same sessions, 100% of mirror responses for P-8572 and 98% of mirror responses for P-857 followed the presentation of the green keylight correlated with the higher FR schedule (FR 100).

Although session length was shorter during the first session following reversal (Session 11) than during the session immediately preceding it, 76% of mirror responses for P-857 and 97% for P-8572 continued to occur in the presence of the green keylight *previously* correlated with the higher FR schedule. During subsequent sessions, however, both the percentage of mirror responses occurring in the presence of the white keylight correlated with the FR 100 schedule and session lengths increased. During the last five sessions under the reversed condition, mean overall rates of mirror responding were 9.7 and 5.2 for P-8572 and P-857, respectively. During those same sessions, 96.7% of all mirror responses for P-8572 and 99.5% of all mirror responses for P-857 occurred in the presence of the white keylight. The cumulative records obtained for P-857 were comparable to those shown for P-8572 in Figure 7. For both pigeons, the shortened session length following the reversal in relationships between key color and FR schedule was probably related to the pigeon's prior exposure in Experiment 1a to a multiple FR 25 FR 25 schedule.

Fig. 7. Cumulative number of key pecks plotted as a function of session time (minutes) for P-8572. Each downward deflection of the pen corresponds to one mirror response and the recorder reset following completion of the FR 100 component on the multiple FR 25 FR 100 reinforcement schedule. The top panel includes the record for the final session in which a white keylight was correlated with an FR 25 schedule and a green keylight with an FR 100 schedule. The bottom panel includes records from the first, second, and fourth sessions following a reversal in relationship between keylight color and FR schedule.

The control of mirror responding by the green keylight in this experiment is comparable to the results of an experiment by Cole and Litchfield (1969) in which a live pigeon target was used instead of a mirror. Following exposure to a multiple FR 66 FR 2 schedule in the presence of a live pigeon, the relationship between the discriminative stimuli and FR schedules was reversed. Immediately following this reversal, responding on the live pigeon continued to occur in the presence of the stimulus *previously* correlated with the FR 66 schedule. Only during later sessions did responding on the live pigeon occur in the presence of the S^D correlated with the higher FR schedule.

EXPERIMENT 1d. RATE OF MIRROR RESPONDING FOLLOWING THE REMOVAL OF A MULTIPLE SCHEDULE

If before conditioning, a food-deprived pigeon is exposed for several sessions to either a

live (Azrin *et al.*, 1966) or taxidermically stuffed (Flory, 1969a) pigeon in an operant chamber, the pigeon's rate of responding on the target pigeon will decrease to relatively low rates over successive sessions. To determine if comparably low rates of mirror responding occur in the presence of mirror-image stimulation alone, both pigeons from the preceding experiments were exposed to a mirror for several sessions with neither food nor discriminative stimuli.

Procedure

Both pigeons were initially exposed to five sessions on a multiple FR 25 FR 100 schedule in which a white keylight was correlated with the FR 100 schedule and a green keylight was correlated with the FR 25 schedule. During the next 10 (P-8572) or 15 (P-857) sessions, the multiple FR 25 FR 100 reinforcement schedule was discontinued. During these sessions, both pigeons were placed in the operant chamber for 1 hr with the mirror available but with neither food hopper nor discriminative stimuli

presented (dark key). Finally, the multiple FR 25 FR 100 schedule used in the initial phase was reintroduced for five sessions for P-8572 and for 10 sessions for P-857.

RESULTS AND DISCUSSION

During the initial five sessions on the multiple FR 25 FR 100 schedule, the median overall rates of mirror responding were 9.71 and 5.23 responses per minute for P-8572 and P-857, respectively. During the last five sessions in which the mirror was presented in the absence of the multiple FR FR schedule, median overall rates of mirror responding decreased to 0.37 and 0.02 responses per minute for P-8572 and P-857, respectively. During these same sessions, median rates of key pecking were 0.02 responses per minute for P-8572 and 0.20 responses per minute for P-857. When re-exposed to the multiple FR 25 FR 100 schedule, rates of mirror responding increased to the original levels. During the last five re-exposure sessions, median overall rates of mirror responding were 8.41 and 4.18 responses per minute for P-8572 and P-857, respectively. Thus, after removal of the multiple FR FR reinforcement schedule, only low rates of mirror responding occurred. This suggests that little if any of the mirror responding observed in Experiments Ia to Ic was controlled by the mirror-image stimulation alone. Control over mirror responding by the multiple FR FR schedule in this experiment is comparable to that reported in other studies (Azrin, *et al.*, 1966; Flory, 1969a) using live and stuffed pigeon targets.

EXPERIMENT II

In Experiment I, the two pigeons that responded on a mirror during exposure to a multiple FR FR reinforcement schedule of key pecking had previously been exposed to the same reinforcement schedule in the presence of live and taxidermically stuffed pigeons. Experiment II determined if such a prior history was a necessary condition to establish and maintain mirror responding on a multiple FR FR schedule.

GENERAL METHOD

Subjects

Three experimentally naive, White Carneaux pigeons obtained from Palmetto Pigeon Plant and maintained under the same living

conditions employed in Experiment I were used in Experiments IIa and IIb.

Apparatus

The apparatus was the same as that used in Experiment I.

EXPERIMENT IIa. ACQUISITION AND MAINTENANCE OF MIRROR RESPONDING DURING MULTIPLE SCHEDULES IN EXPERIMENTALLY NAIVE PIGEONS

Training Procedure without Mirror

During the initial training phase, the mirror used in Experiment I was removed from the chamber. During the first experimental session, pigeons were hopper trained, shaped to peck an alternating green and white response key, and exposed to a continuous reinforcement schedule. Following this session, the pigeons were exposed to a multiple FR FR schedule in which the ratios were gradually increased over 35 to 40 sessions to a multiple FR 25 FR 100 schedule for P-796 and P-430 and to a multiple FR 25 FR 75 schedule for P-444. Pigeons were exposed to the last FR FR schedule for 10 to 14 sessions. As in Experiment Ia, the fixed component (FR 25) was correlated with a white response key and the varied component (FR 75 or 100) was correlated with a green response key. Within each session, the schedule components alternated with one reinforcement occurring in each component. Daily sessions, which were generally conducted six days per week, were terminated after either 60 reinforcements or 90 min, whichever occurred first.

Training Procedure with Mirror

During this phase, the mirror was located in the chamber at the same place that it was mounted in Experiment I. After introduction of the mirror, P-796 and P-430 were given 10 additional sessions under the FR 25 FR 100 schedule and P-444 was exposed to 10 more sessions on the FR 25 FR 75 schedule. After the tenth session with the mirror present, each pigeon was exposed to an additional 10 sessions on the same schedule if all 60 reinforcements were not delivered in each of the preceding five sessions. If all 60 reinforcements were delivered during the last five sessions, the FR schedule in the varied component was in-

creased by 25 for the next 10 sessions. For each pigeon, this procedure was repeated until the subject did not meet the criterion for increasing the FR schedule in the varied component within 20 sessions. At this point, only those pigeons that exhibited sustained responding on the mirror were exposed for 10 sessions to a multiple FR 25 FR 25 schedule and then re-exposed to the immediately preceding FR FR schedule for 10 sessions.

RESULTS AND DISCUSSION

Figure 8 plots for the three pigeons overall rate of mirror responding (total responses/session length), local rate of mirror responding (total responses/cumulative post-reinforcement pause time), and reinforcement rate (reinforcements/session length) as a function of successive sessions. Two of the three pigeons (796 and 444) exposed to the multiple FR FR schedules exhibited sustained rates of mirror responding. Whereas none of the pigeons showed sustained overall or local rates of

mirror responding on the multiple schedule in which the mirror was first introduced, P-796 and P-444 did so on the second schedule (Sessions 11 to 30) to which they were exposed. Median overall rates of mirror responding during the last five sessions on the multiple FR 25 FR 125 schedule (P-796) and on the multiple FR 25 FR 100 schedule (P-444) were 3.2 and 1.1 response per minute respectively. As indicated in Figure 8, the development of mirror responding was not correlated with a change in reinforcement rate for either bird. As was the case in Experiment I, virtually all mirror pecks occurred during the post-reinforcement pause following the presentation of the discriminative stimulus correlated with the higher FR schedule. For the third pigeon, P-430, an increase in the FR schedule in the varied component from 100 to 200 (Sessions 1 to 70) and the corresponding decrease in reinforcement rate was not accompanied, at any value, by a sustained rate of mirror responding.

Fig. 8. Overall rate of mirror responding (total responses/session length), local rate of mirror responding (total responses/cumulative post-reinforcement pause time), and reinforcement rate (total reinforcements/session length) plotted as a function of successive sessions for P-796, P-444, and P-430. The vertical dashed lines correspond to changes in the FR schedule in the varied component. The absence of local rate data corresponds to sessions in which local rate of mirror responding was not available.

For both P-796 and P-444, a subsequent decrease and then increase in the FR schedule in the varied component was accompanied by a corresponding decrease and then increase in overall and local rates of mirror responding. During exposure to the multiple FR 25 FR 25 schedule (Sessions 31 to 40), median overall rates of mirror responding decreased to 0.6 and 0.0 responses per minute for P-796 and P-444, respectively. When subsequently re-exposed to the higher FR schedules (Sessions 41 to 50), median overall rates of mirror responding increased to 3.5 responses per minute for P-796 and to 1.7 responses per minute for P-444.

In summary, the data indicate that prior exposure to a multiple FR FR schedule in the presence of a live and stuffed pigeon is not, for all pigeons, a necessary condition for the establishment and maintenance of mirror responding on that schedule. In this respect, these results are comparable to those observed in similar experiments (*e.g.*, Flory, 1969*a*) involving a taxidermically stuffed pigeon target instead of a mirror.

EXPERIMENT IIb. A REPLICATION OF EXPERIMENT Id

After removal of the multiple FR FR reinforcement schedule for key pecking in Experiment Id, very low rates of mirror responding occurred in the presence of mirror-image stimulation alone. The next experiment was conducted to determine if this would also be the case for the two pigeons that exhibited sustained mirror responding in Experiment IIa.

Procedure

P-796 and P-444 were given 10 additional sessions on the same multiple FR FR schedules used at the end of Experiment IIa. During the next 10 sessions, the multiple schedule was discontinued for both birds. During each of these sessions, the pigeon was placed in the operant chamber for 1 hr with the mirror available but with neither food hopper nor discriminative stimuli presented (dark key). Following the tenth session on this procedure, P-796 and P-444 were re-exposed for five and 10 sessions, respectively, to the same multiple schedule used in the immediately preceding sessions.

RESULTS AND DISCUSSION

During the last five sessions on the multiple FR FR schedule in Experiment IIa, the median overall rates of mirror responding were 6.1 and 1.6 responses per minute for P-796 and P-444 respectively. Following the removal of the multiple schedule, the rates of mirror responding decreased to medians, over the last five sessions, of 0.02 mirror responses per minute for P-796 and to 0.0 mirror responses per minute for P-444. When re-exposed to the multiple FR FR schedule, rates of mirror responding returned to medians during the last five sessions of 4.19 responses per minute for P-796 and 1.26 responses per minute for P-444. As was the case in Experiment Id, mirror-image stimulation in the absence of a multiple FR FR schedule was not a sufficient condition for maintaining mirror responding.

GENERAL DISCUSSION

If a pigeon receives reinforcement for pecking a response key on multiple FR FR reinforcement schedules in the presence of either a live or taxidermically stuffed pigeon, the subject will often charge, peck, and pluck the feathers from the target pigeon after the S^D correlated with the higher FR schedule is presented. The combined results from several experiments (*e.g.*, Cole and Litchfield, 1969; Flory, 1969*a*; Knutson, 1970) have shown that such responding on the target pigeon is controlled by several properties of the multiple reinforcement schedule, including the FR schedule and S^D within each component. In general, the results of Experiments I and II demonstrated that within a single animal, the topography and temporal pattern of mirror responding that occurred during exposure to a multiple FR FR schedule was comparable to the responding on live and stuffed targets reported in the previous studies.

Flory (1969*b*) demonstrated that when a pigeon is exposed to schedules of response-independent food presentation in the presence of a stuffed pigeon, there is an inverted U-shaped relationship between rate of responding on the stuffed pigeon and the minimum inter-food intervals, ranging from 0.25 to 16 min. The fact that there was also an inverted U-shaped relationship between rate of mirror responding and inter-food intervals over the same range

in Experiment Ia suggests that, for pigeons, the relationship between rate of target responding and reinforcement schedule is controlled more by the inter-food intervals resulting from that schedule than by the arranged reinforcement contingency.

The fact that pigeons in Experiments I and II exhibited sustained rates of mirror responding during exposure to multiple FR FR schedules suggests that in studies involving reinforcement schedules, reflective surfaces such as one-way mirrors and stainless steel walls may control a considerable amount of the pigeon's behavior. On the other hand, in studies specifically concerned with schedule-induced responding, using a mirror instead of either a live or stuffed target has the combined advantages of (1) providing a more stable, although not perfectly constant, target within and across experimental sessions, (2) eliminating severe injury that occurs to unshielded live targets and often results in loss of experimental time, (3) eliminating spuriously high rates of target responding due to contact bounce or movement of a target, and, (4) reducing the cost of the target.

It is of interest that mirror-image stimulation in both experiments maintained high rates of mirror responding in spite of the fact that the visual and tactile feedback specific to the responding on live and stuffed targets in other studies was eliminated. For example, in the present study, pigeons charged and pecked at the mirror-image stimulation, but could not grasp, shake, or peck it at any place other than on the beak. In this respect, these results are similar to naturalists' observations (e.g., Allen, 1963; Dickey, 1916; Ritter, 1934) that during mating season birds such as the Cardinal (*Richmondia Cardinalis*) and the Brown Towhee (*Pipilo Fuscus*) often charge and peck at reflective surfaces such as hubcaps and window panes.

Finally, the fact that pigeons in this study exhibited schedule-induced responding on a hard, two-dimensional mirror raises the possibility of using other two-dimensional stimuli such as photographs, projected slides, movies, and drawings for studying the necessary and sufficient target conditions needed to establish and maintain responding on the target, for studying the localization of responding on the target, and for providing a baseline condition for studying concept formation in the pigeon (Poole and Lander, 1971).

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