SPATIOTEMPORAL PATTERNS OF BEHAVIOR PRODUCED BY VARIABLE-INTERVAL SCHEDULES OF REINFORCEMENT

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The spatiotemporal patterns of behavior exhibited by two pigeons during a variable-interval 15-second schedule of food reinforcement, a variable-interval 5-minute schedule, and then extinction of key pecking were recorded using an apparatus that continuously tracked the position of the bird in the experimental chamber. The variable-interval 15-second schedule produced a close-to-key pattern between reinforcements with two types of regular excursions from the region of the key frequently occurring after reinforcement. Subsequent exposure to the variable-interval 5-minute schedule produced more extended and extremely regular patterns between responses. Reinstatement of the variable-interval 15-second schedule reestablished the close-to-key pattern with regular excursions frequently occurring after reinforcement. During extinction the spatiotemporal patterns that had developed during the variable-interval 5-minute schedule reappeared and gradually dissipated. These patterns may have been a form of superstitious behavior.

Key words: spatiotemporal behavior patterns, variable-interval schedules, extinction, interresponse-time reinforcement, adventitious reinforcement, superstitious behavior, schedule-induced behavior, pigeons

There is evidence that rate of responding in variable-interval (VI) schedules, in which reinforcement is contingent on the first response after a varied interval of time following the previous reinforcement, is determined jointly by two factors: (1) rate of reinforcement, and (2) an implicit contingency whereby certain interresponse times (IRTs) are differentially reinforced. Because independent manipulation of these two factors is precluded by the definition of VI schedules, modified VI schedules have been used to isolate their separate effects. For example, Shimp (1974) used a "synthetic" VI schedule that arranged reinforcement with equal probability to 10 IRT class intervals. He found that the time allocated by pigeons to emitting IRTs in all these class intervals, considered together, varied di-

rectly with rate of reinforcement. Further, the relative time allocated to each of these class intervals roughly equaled the relative rate of reinforcement for that class interval. Platt (1979) used a schedule in which the probability of reinforcement was proportional to the length of the current IRT or of the fifth preceding IRT, which permitted independent manipulation of rate of reinforcement and the IRT reinforcement contingency presumed to be operating in VI schedules. He found that pigeons' rate of responding varied directly with rate of reinforcement both when the IRT contingency was present and when it was absent, and was higher when the contingency was absent.

To speak of reinforcement of an IRT implies that time of occurrence is a reinforceable property of behavior. The reinforceable property that is reflected in an IRT may, however, have a significant spatial as well as temporal component. It seems to follow from Skinner's (1948) concept of superstitious behavior that specific IRTs may be reinforced on VI schedules because, since the behavior occurring prior to a reinforced response is unspecified by the VI contingency, various spatiotemporal patterns of behavior may tend to

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be adventitiously reinforced. There is support for this hypothesis. For example, Hearst, Koresko, and Poppen (1964) observed pigeons to engage in stereotyped sequences of behavior during a VI schedule. These stereotyped sequences were more likely to develop during long VI schedules than during short ones, which is consistent with the fact that long VI schedules tend to generate long IRTs. Moreover, Pear, Rector, and Legris (1982), using an apparatus that continuously tracked the distance of a pigeon's head from the response key, recorded very regular spatiotemporal patterns during a VI schedule. These patterns differed for the 2 birds in the experiment and changed across sessions, as would be expected if they were generated and maintained by adventitious reinforcement.

A refinement of the apparatus used by Pear et al. (1982) was used in the present experiment to test further the hypothesis that VI schedules generate superstitious behavior between responses. In the present experiment, key pecking by pigeons was first developed on a short VI schedule. Next, a long VI schedule was introduced to determine whether the spatiotemporal behavior patterns constituting the long IRTs thereby generated would be highly regular, as would be expected if superstitious behavior were involved. A reversal back to the short VI schedule was then performed to assess the recoverability of the original pattern. Finally, extinction was carried out to discover whether the spatiotemporal patterns that had developed on both VI schedules would occur and dissipate, as would be expected of previously reinforced behavior during extinction. Such a finding for the spatiotemporal patterns constituting the long IRTs during the long VI schedule would suggest that those patterns were superstitious, inasmuch as superstitious behavior should extinguish in a manner similar to that of other operant behavior (cf. Lyon, 1982).

METHOD

Subjects

Two adult, male, experimentally naive White Carneaux pigeons were maintained at

approximately 80% of their free-feeding weights. The free-feeding weight of Bird 3084 was 580 g, and that of Bird 1692 was 595 g. For the purpose of tracking the movements of the birds with the computer system described below, their heads and necks were darkened with black shoe polish prior to each session. When not in a session, the birds were housed in individual cages in a pigeon colony room that was regulated by a 12-hr-on/12-hr-off light-dark cycle. The pigeons' diet in their home cages consisted of Purina Racing Pigeon Checkers, which was the same food used for reinforcement during experimental sessions.

Apparatus

The experimental chamber and the programming and recording equipment were located in separate rooms. The room containing the experimental chamber was illuminated by four banks of fluorescent lights in open light fixtures on the ceiling. The lights were wired through a relay that was under the control of the programming equipment. Ventilation of the room was provided through a register in the ceiling.

A steel frame supported the top and sides of the chamber, the inside dimensions of which were 57 by 57 by 38 cm. The front wall of the chamber was made of an aluminum panel and two pieces of white opaque Plexiglas, each of which was attached to one side of the panel. The left adjacent wall was made entirely of white opaque Plexiglas, and the other two walls were made of clear glass. The top of the chamber was made of clear Plexiglas and the floor was aluminum mesh fitted into a stainless steel drop pan. The interior of the chamber was illuminated through the top and the two transparent sides by the room lights, which were on during sessions and were turned off automatically when each session was completed. Numerous air spaces in the top and bottom of the chamber provided ventilation. A speaker in the room produced white noise continuously to mask sounds from outside the room.

Mounted on the aluminum panel of the front wall were: (1) a translucent plastic response key, which was 2.75 cm in diameter

with its center located 26 cm from the mesh floor and 21 cm from the left adjacent wall; and (2) the feeder aperture, which was equidistant from the side walls and the bottom of which was located 13.5 cm from the floor. The key required a force of 0.18 N to record a peck, and was illuminated continuously with white light during sessions, except during feeder operations when the key was dark. Operation of an electrical relay behind the key produced an auditory stimulus each time the key was pecked during the session, except during feeder operations. The feeder aperture was illuminated continuously by two SL-313 bulbs in series with a 33-ohm resistor. During reinforcement, which consisted of 3-s access to the filled food hopper, the brightness of the feeder light was increased by the elimination of the resistor from the circuit.

The experimental room also contained two perpendicularly oriented TV cameras that were directed towards the two clear glass walls of the chamber. The cameras were connected to an electronic video-acquisition module that computed the position in space and time of the top center of the highest dark region viewed by each camera. The spatial x coordinate was computed on one camera and the yz coordinates were computed on the other camera. These computations were made 30 times per second, so that the target was tracked almost continuously. Because the pigeon's head was painted black, and the rest of the interior of the chamber was white and well illuminated, the head was the target tracked by the system. To avoid interference of the tracking system by the metal joints connecting the glass walls, the chamber was turned at an angle of 15° to the cameras. This resulted in three narrow slices of the periphery of the chamber being excluded from the view of the cameras.

The video-acquisition module was connected to a Cromemco Z-2D microcomputer that collected the data, averaged the data points in groups of three, and stored the data on floppy disks for later analysis. This microcomputer was also used to program the experiment. An Epson dot matrix printer, controlled by the computer, was used to graph the data.

A block diagram of the apparatus has been published in an earlier issue of this journal (Pear & Eldridge, 1984, Figure 1, p. 461).

Procedure

The birds were trained to eat from the feeder and pecking of the response key was shaped by means of food reinforcement; then for several sessions, every key peck was reinforced. They were then exposed to the following sequence of schedules: VI 15 s for 95 sessions, extinction (no reinforcement) for 1 session, VI 15 s for 16 sessions, VI 5 min for 43 sessions, VI 15 s for 16 sessions, and extinction for 6 sessions. The intervals in each VI schedule were determined by a pseudorandom probability generator that generated numbers between 0 and .99. Schedule values in seconds were doubled, one was added to the result, and all numbers in the probability distribution were multiplied by that number. The number of seconds in a given interval was the integer value of the final results.

Each session terminated after 60 reinforcers or after 1 hr of session time, whichever occurred first. Reinforcement time was subtracted from total time in calculating session time, and was excluded from all data analyses. Sessions were conducted daily, at approximately the same time each day, 5 or 6 days per week.

RESULTS

The tracking system was not functional until Sessions 42 of the first series of sessions of VI 15 s. By that time both birds were behaving in very regular patterns on the schedule. During extinction in the session following Session 95 of VI 15 s, the pattern of behavior became very irregular (i.e., variability increased) as key pecking decreased. Upon the reintroduction of VI 15 s, the original patterns quickly returned and were maintained until the introduction of VI 5 min.

Figure 1 shows data from the last session of VI 15 s prior to the introduction of VI 5 min. The top left graph for each bird is a cumulative record of the key pecks that occurred during that session, which was 975 s long for both birds (because the sequence of random num-

Bird 3084

VI 15 Sec Last Session

Bird 1692

VI 15 Sec Last Session

Fig. 1. Last session of the first exposure to VI 15 s for each of the 2 birds. Cumulative responses over the session are plotted in the top left graph for each bird, and distance of the bird's head from the key over the session is plotted in the top right graph (where each point is an average of three data points sampled at 1/30-s intervals). Key pecks are indicated by vertical lines in the upper band below each of these graphs; reinforcers are indicated by vertical marks in the lower band. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band (none occurred during this session). Expansions of the regions between a and b and between c and d are shown in the middle two graphs. (The arrows indicate the reinforcement markers, which are difficult to see because of the magnitude of the reduction.) Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. The positions of the key and feeder are indicated by "k" and "f" in the overhead plots. The dotted lines indicate regions that were outside the range of the cameras.

bers used to generate the VI schedule was the same for both birds on each session). These cumulative records were produced by the computer rather than by a standard cumulative recorder. The horizontal band just below each cumulative record shows key pecks as vertical marks that, because of their density, form a solid black strip. Reinforcements are shown as short vertical marks in the center of the lower band. The top portion of the lower band was reserved for indicating errors in the tracking system. Errors were defined as instances in which (1) either camera failed to detect a dark region in the chamber, or (2) the target being tracked moved at a speed greater than 10 cm/s, which would indicate that a spurious dark target (e.g., a shadow) was being tracked momentarily. Such errors typically occurred when the pigeon obscured its head and neck by flapping its wings or by preening under its wings. No errors were recorded during the last session of VI 15 s for either bird.

The top right graph for each bird shows the absolute distance of the bird's head from the key over the session. Each point is based on the mean of three computations of each of the spatial coordinates in which the target was detected by the system at 1/30-s intervals. Thus, successive points indicate the mean distance of the bird's head from the key at 1/10-s intervals. The two horizontal bands below this distance plot contain the same information as those below the cumulative record. Note from both the cumulative records and the corresponding distance plots that each bird pecked the key at a fairly constant rate and typically stayed close to the key throughout most of the session. Bird 1692 pecked at a higher rate than did Bird 3084, and was also less variable in the distance it moved from the key. Both birds, however, made a number of excursions from the key.

The graphs in the middle row show expansions of the regions between a and b and between c and d in the above distance plots. These regions were selected as being reasonably typical of the behavior occurring throughout the session. Note that the excursions from the key typically occurred immediately after reinforcement. For Bird 3084, two types of ex-

cursions after reinforcement occurred: long and short excursions. Unlike the former, the latter usually occurred repetitively for a short period. For Bird 1692, only long excursions occurred after reinforcement. In addition, not all reinforcements produced excursions; in some cases the bird returned to the key immediately after reinforcement, as can be seen by the very small increases in distance above some of the reinforcement indicators.

The bottom graphs show plots of the patterns described by the birds' movements in the *xy* plane (i.e., overhead plots) during the periods shown in the distance plots immediately above. The dotted lines in the overhead plots indicate the regions that were not visible to the camera (see explanation in the apparatus section). For both birds the excursions indicated by "c" in the above distance plots were clockwise circuits that can be seen clearly in the overhead plots. For Bird 3084 the short excursions were typically back-and-forth movements to the right of the key.

Figure 2 shows data from the first 1200 s and the last 1200 s of the last session of VI 5 min (the middle 1200 s have been excluded to conserve space). It can be seen from the cumulative records in the top row that both birds responded at lower rates during the last session of VI 5 min than they did during the last session of VI 15 s (cf. Figure 1). This is consistent with numerous demonstrations in the literature that long VI schedules generate lower rates of responding than do short VI schedules (e.g., Catania & Reynolds, 1968; Clark, 1958; Ferster & Skinner, 1957). Interestingly, Bird 1692 responded at a lower rate than Bird 3084 during VI 5 min although it had responded at a higher rate during VI 15 s. The distance plots in the second row show that both birds moved farther from the key between responses during VI 5 min than they typically did during VI 15 s. These excursions can be seen to be fairly regular, but much detail is missing in these plots. In an attempt to display representative detail in the excursions, 2-min segments were taken near the beginning and near the end of the session for each bird, and are expanded in the third row. Note that for Bird 3084 there was a repetitive pattern

Bird 1692
VI 5 Min Last Session

Bird 3084
VI 5 Min Last Session

Fig. 2. Last session of the VI 5-min schedule for each of the 2 birds. The cumulative record of the first 1200 s of the session is shown in the top left graph for each bird, and that of the last 1200 s is shown in the top right graph (the middle 1200 s period is not shown). Distance of the bird's head from the key over the first and last 1200 s of the session is shown in the second row of graphs. Expansions of the regions between a and b and between c and d are shown in the third row of graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. Details are the same as for Figure 1.

consisting of two long excursions (labeled "r" and "l") typically followed by several shorter excursions. The overhead plots of these segments are shown in the bottom row. The pattern depicted consisted of two types of circuits, where the circuits on the right corresponded to the excursions labeled "r" and the circuits on the left corresponded to the excursions labeled "l." Right and left circuits tended to alternate, with the right circuit being executed in a clockwise direction and the left circuit in a counterclockwise direction.

For Bird 1692 the expanded 2-min segments in the third row also show regularity. Bursts of several key pecks were followed by long excursions usually of about the same length. As indicated by the overhead plots below the expanded distance plots, these excursions corresponded to two distinct patterns: (1) an elongated "figure-eight" pattern to the right of the key, and (2) a circling pattern. The circling pattern consisted of both clockwise and counterclockwise circuits, indicated by *c* and *c'*, respectively, in the expanded distance plots. The clockwise and counterclockwise circuits usually alternated in this particular session, although this was not necessarily the case in previous sessions. The first part of the "figure-eight" pattern was clockwise and the second part was counterclockwise. Note that both the alternating-circuits pattern and the "figure-eight" pattern occurred in the 2-min segment taken from the first part of the session, but only the "figure-eight" pattern occurred in the 2-min segment taken from the last part of the session. In addition, the "figure-eight" pattern was less rounded in the last part of the session.

In Figures 3 and 4 an attempt was made to provide some additional information about the pattern that Bird 3084 developed on VI 5 min. These data were subjectively chosen for presentation after careful scrutiny of the data from numerous sessions, and are believed to be representative of the pattern that eventually developed and of the general manner in which it developed. Figure 3 shows in detail a 24-s sequence of the pattern from an overhead perspective. Segment 1 is from second 3422 of the session, and each successive segment contains

data from the preceding segment and adds 1 s of data. The sequence begins at the arrow in Segment 1, where the bird approached the key, pecked it, and then moved back toward the right. The bird continued in a clockwise direction until, in Segment 5, it again reached the key. From Segment 6 to 9 the bird executed a counterclockwise circuit to the left of the first circuit. From Segment 10 to 15 the bird moved back and forth, pecking the key on each approach. From Segment 16 to 18 the bird executed another clockwise circuit to the right. From Segment 19 to 22 the bird executed another counterclockwise circuit to the left. The bird then made several back-and-forth movements. The key pecks emitted by the bird during Segments 1 to 24 are shown as vertical lines in the band above the time scale at the bottom.

Figure 4 shows overhead plots of selected 2-min segments from the first to the fourth from last session of VI 5 min. In selecting these segments an attempt was made to obtain examples that resembled the pattern that eventually developed as depicted in Figure 2, in order to give some indication of the manner in which that pattern emerged. Although elements of the pattern are evident in each of these plots, the "complete" pattern was not observed until Session 16. Even after Session 16, however, the pattern was not entirely stable; it changed considerably both within and across sessions. On Session 39, in fact, it was replaced temporarily by a quite different pattern, consisting mainly of pacing back and forth from the key to the right wall and along the right wall. The former pattern returned on the following session and remained for the next three sessions, after which the VI 5-min phase of the study was terminated. Although the behavior still may not have been completely stable at that time, the primary purpose of the phase had been achieved in demonstrating the emergence of a fairly coherent pattern.

A detailed analysis of the development of the two patterns exhibited by Bird 1692 at the end of the VI 5-min phase yielded results similar to the above, but to conserve space will not be presented. As with the pattern developed

Bird 3084
VI 5 Min Last Session
3422 - 3446 sec

Fig. 3. One-second segments of a 24-s period during the last session of VI 5 min for Bird 3084, illustrating the manner in which the bird executed the double-circuits pattern. The panels numbered 1 to 24 show the positions of the bird's head from an overhead view in consecutive 1-s segments, where each segment includes the data from the previous segments. Each point is an average of three determinations of the bird's head taken at 1/30-s intervals. The vertical lines in the band at the bottom of the figure indicate the times at which key pecks occurred during the 24-s period.

Bird 3084
Sample Patterns From VI 5 Min

Fig. 4. Overhead plots for sample 120-s periods from Sessions 1 to 40 of VI 5 min for Bird 3084, illustrating the development of the double-circuits pattern over sessions.

Fig. 5. Last session of the second exposure to VI 15 s for both birds. Details are the same as for Figure 1.

Bird 1692
EXT First Session

Bird 3084
EXT First Session

Fig. 6. First session of extinction following the second exposure to VI 15 s for both birds. Details are the same as for Figure 2.

by Bird 3084, the alternating-circuits and "figure-eight" patterns developed by Bird 1692 emerged gradually.

Figure 5 shows data from the last session of VI 15 s after the reintroduction of that session following VI 5 min. Note that for each bird, rate of responding had increased from its level under VI 5 min (Figure 2), the bird was closer to the key for most of the session, and excursions from the region of the key were similar to those that occurred during the original exposure to VI 15 s (Figure 1). This reversal in the behavior occurred much earlier than the session shown here, being essentially complete by the end of the first session of the reintroduction of VI 15 s.

Figure 6 shows data from the first session of extinction immediately after the session shown in the previous figure. Only the first and last 1200 s are shown. From the cumulative record of each bird (top row) it can be seen that key pecking gradually decreased over the session. From the distance plots (second row) it can be seen that although each bird's session began with short excursions from the key, long excursions gradually came to predominate.

The mixture of short and long excursions during extinction for both birds appears to reflect the extinction of the patterns developed under both VI 15 s and VI 5 min. To illustrate this point, 2-min segments taken during the early and later parts of each bird's session are shown expanded in the third row of the figure. In selecting the early segment, an effort was made to sample both short and long excursions. Note that in the early segment for Bird 3084, a series of long excursions is followed by a series of short excursions. The overhead plot corresponding to this segment, which is presented below it, shows that the long excursions consisted of the double-circuits pattern that had developed on VI 5 min (see Figure 2). As during the last several sessions of VI 5 min, right and left circuits alternated as indicated in the expanded 2-min segments. Note that in the early segment for Bird 1692, short and long excursions are intermixed. The overhead plot of this segment shows that the long excursions consisted of the two patterns that had developed on VI 5 min: (1) an elon-

gated "figure-eight" pattern, and (2) a circling pattern. As during the last session of VI 5 min, clockwise and counterclockwise circuits tended to alternate, as indicated in the expanded segments.

For both birds the patterns that had developed under the VI schedules deteriorated to the point that little remained of them by the end of the first extinction session. As can be seen from the expanded distance plots taken from near the end of the session, and the corresponding overhead plots, the pattern that came to predominate for both birds was that of pacing along the right side wall (it may be relevant that this wall was transparent, whereas the left side wall was opaque) with interspersed trips to the key. In the next session, the previous patterns recovered, but then deteriorated in a fashion similar to that of the first extinction session. Over the next several sessions of extinction, approaches to the key and other behavior decreased to the point that eventually both birds simply remained motionless some distance from the key for long periods of time.

To show more clearly the extinction of the two patterns developed by Bird 1692, Figure 7 presents four overhead plots of data presented for that bird in the previous figure. The two top plots are from the early part of the session and the bottom plots are from the later part of the session. The top left plot shows the alternating-circuits pattern; the top right plot shows the elongated "figure-eight" pattern; the bottom left plot shows the right-wall pacing that emerged as extinction progressed; the bottom right plot shows alternating circuits with interspersed right-wall pacing.

DISCUSSION

For the most part, the VI 15-s schedule produced a close-to-key pattern between responses. Extended spatiotemporal patterns of behavior developed when the value of the VI schedule was increased from 15 s to 5 min. Over sessions the extended patterns became very regular, although never perfectly stable as indicated by the fact that they changed to some extent both within and across sessions. The close-to-key pattern returned very quickly

Bird 1692
EXT First Session

Fig. 7. Selected overhead plots from the first session of extinction for Bird 1692. Letters indicating where the excursions occurred in the session correspond to the letters in the previous figure.

when the value of the VI schedule was changed back to 15 s. During the subsequent extinction phase, the patterns that had developed under each of the two schedules appeared and gradually deteriorated as extinction progressed. It therefore seems likely that the extended spatiotemporal patterns were superstitious behavior that had been reinforced on the long VI schedule. The most likely alternative explanation is that the extended patterns that developed in the VI 5-min schedule were "schedule-induced" rather than adventitiously reinforced (Staddon, 1977). If this is the case, however, it is not clear why those patterns appeared during extinction when the schedule that had originally generated them was not in effect, and had not been in effect recently. This supports the view that adventitious reinforcement of extended spatiotemporal patterns is responsible

for the differential reinforcement of long IRTs in VI schedules (Morse, 1966; Platt, 1979).

The regularity in the patterns that developed under VI 5 min was striking. Similar regularity in behavior was reported by Schwartz (1980, 1982), who found that pigeons developed stereotyped response sequences on two keys when reinforcement was contingent on a certain number of pecks in any order on each key. His finding is compatible with the present results, because spatial cues (the position of a light in a matrix) were correlated with the number of pecks on each key and distributing pecks between two keys had important spatial components. In addition, there is evidence that sequential dependencies between IRTs can develop on various schedules of reinforcement (e.g., Blough, 1966; Shimp, 1973; Williams, 1968). Although no statistical analysis

was performed on the IRTs in the present experiment, examination of several of the figures shows clearly that sequential dependencies were present. For example, it can be seen in Figure 3 that short IRTs in which the bird was close to the key were frequently followed by longer IRTs corresponding to the right and left circuits that the bird executed.

It is interesting to note that several spatio-temporal patterns can be developed and maintained simultaneously by the same schedule of reinforcement. There are two examples of this in the present data. One example is the close-to-key behavior between reinforcers and the circling and back-and-forth movements of both birds following reinforcement on VI 15 s. The other example is the "figure-eight" and alternating-circuits patterns that were exhibited by Bird 1692 on VI 5 min. A possible explanation of such simultaneously maintained patterns is that they were under the control of particular stimuli as a result of having been adventitiously reinforced in the presence of those stimuli (cf. Morse & Skinner, 1957). Verification of this explanation would require identification of the controlling stimuli, which might be generated by behavior or might simply be correlated with the passage of time.

It should be noted, however, that there is a strong possibility that the circuits that occurred immediately after reinforcement on VI 15 s were schedule-induced. Staddon and Simmelhag (1971) reported similar circling by pigeons immediately after noncontingent reinforcement delivered at short fixed-time intervals, and it seems unlikely that such patterns could have been adventitiously reinforced because they did not continue to the end of the interval. The regular patterns that developed during VI 5 min in the present study, however, did not occur immediately after reinforcement; in fact, the patterns that occurred immediately after reinforcement appeared to be quite irregular.

The present results are consistent with Shimp's (e.g., 1975, 1982a, 1982b) contention that discrete responses such as key pecks are not appropriate units of behavior because they do not incorporate behavior patterns that appear to be under the control of the reinforce-

ment contingency. The double circuits, alternating circuits, and "figure-eight" patterns recorded in the present experiment appear to be examples of such patterns. That these patterns were under the control of the reinforcement contingency is indicated by their gradual development when the birds were exposed to VI 5 min and by their gradual dissipation during extinction (e.g., Figures 4, 6, and 7).

Thus, a change in a schedule parameter can result not only in a change in response rate, but also apparently in a qualitative change in the behavior that occurs between discrete responses. It seems to follow that rate of a discrete response such as a key peck may not be a completely satisfactory measure of the behavior controlled by a given schedule of reinforcement. The question therefore arises as to what would constitute a more satisfactory measure. This question is difficult to answer because there seem to be two probabilities concerning behavior that we might reasonably wish to measure: (1) the probability of the occurrence of a specific discrete response; (2) the probability of the occurrence of the spatiotemporal pattern in which the discrete response is embedded. One possible solution to this problem is to use response rate as a measure of the former and the proportion of time allocated to the spatiotemporal pattern as a measure of the latter (e.g., Pear & Rector, 1979). Extensions of the method of the present experiment may prove useful in further quantifying spatiotemporal patterns of behavior produced by various schedules, and thus help to advance our understanding of schedule-controlled behavior.

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