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# TOPOGRAPHICAL VARIATIONS IN BEHAVIOR DURING AUTOSHAPING, AUTOMAINTENANCE, AND OMISSION TRAINING

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Three pigeons were exposed to an autoshaping and automaintenance procedure while a computer-controlled tracking system continuously recorded the position of the bird's head as it moved freely in the experimental chamber. Although only 2 birds pecked the key during the conditional stimulus (red keylight), all 3 birds exhibited stable patterns of approaching the conditional stimulus and withdrawing from the intertrial stimulus (white keylight). Subsequent exposure to an omission procedure, in which pecks on the red key cancelled the presentation of food upon the termination of the red keylight, greatly reduced key pecking, but approaching and pecking in the vicinity of the conditional stimulus were maintained at high levels. When the omission contingency was removed key pecking increased. During all phases the birds withdrew from the area of the white key and engaged in repetitive back-and-forth or circuiting movements during this intertrial stimulus. The data document (a) the strong control the conditional stimulus in autoshaping and automaintenance exerts over approach to the key and pecking motions whether or not the conditional stimulus elicits key pecking at a high level; and (b) withdrawal from the vicinity of the key and the occurrence of stereotypic behavior during the intertrial interval.

*Key words:* automaintenance, autoshaping, omission training, response reinforcer, stimulus reinforcer, key peck, pigeons

A stimulus that is paired with a reinforcer may come to elicit responses directed toward it. For example, pecking at a lighted key can be developed and maintained in pigeons by the response-independent pairing of a keylight with the operation of a feeder (Brown & Jenkins, 1968). Although this phenomenon is termed *autoshaping* during the conditioning stage and *automaintenance* during the maintenance stage, for convenience we shall use the former term in reference to both of these stages. Autoshaping is of particular interest because it represents an example of a directed skeletal response under the apparent control of a Pavlovian conditioning procedure. However, the mere existence of a Pavlovian stimulus-reinforcer relationship does not ensure that the behavior in question is controlled, completely or in part, by that relationship. Indeed, many studies point to the interaction of stimulus-reinforcer and response-reinforcer relations in the control of autoshaped key pecking (e.g., Woodruff, Conner, Gamzu, & Williams, 1977).

In a variation of autoshaping called omission training, a peck on the stimulus (referred to here as the *conditional stimulus* or CS) that is paired with a reinforcer cancels the reinforcer following the CS. This procedure typically results in substantially reduced levels of responding, indicating at least some measure of operant control (Atnip, 1977; Jenkins, 1981; O'Connell, 1979; Schwartz & Williams, 1972; Stiers & Silberberg, 1974; Wasserman, Hunter, Gutowski, & Bader, 1975; Williams & Williams, 1969; Woodard, Ballinger, & Bitterman, 1974). Several studies have described topographical changes from autoshaping to omission training; however, these studies have relied primarily on visual observation (e.g., Barrera, 1974) or on gross measures of the pigeon's position in the chamber (e.g., Hearst & Jenkins, 1974; Lucas, 1975; Wessells, 1974).

In the present study, we used a specially constructed apparatus that recorded the spatial

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coordinates of a hypothetical dark point on the pigeon's head as the bird moved freely in the chamber, engaging in key pecking and other activities (Pear, 1985; Pear & Eldridge, 1984). These spatial coordinates were sampled 30 times per second, providing a nearly continuous record of head movements and changes in the bird's position in the chamber throughout the entire session. The primary aim of the study was to obtain a more complete description than previously available of pigeons' response topography in both the presence and the absence of the CS during autoshaping and omission training. We also were interested in obtaining a topographical record of the sequence of behavior patterns that culminated in the first key peck. Previously, only anecdotal accounts of this sequence have been reported.

## METHOD

### *Subjects*

Three experimentally naive male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights throughout the study. In order for the apparatus to track the movements of the birds, their heads and necks (excluding the beaks) were blackened with shoe polish prior to each session. The birds were housed in individual cages in a colony room regulated by a 12:12 hr light/dark cycle. Water was freely available in the home cages.

### *Apparatus*

A specially constructed operant chamber for pigeons was used. The front wall, which contained the response key and food hopper, was constructed of white opaque Plexiglas® and aluminum painted white. The left wall was also made of white opaque Plexiglas®; the other two walls were clear glass, and the lid was clear Plexiglas®. An aluminum frame supported the walls and lid. The floor was an aluminum mesh fitted over an aluminum drop pan. The chamber measured 57 by 57 by 38 cm.

The chamber was illuminated through the transparent sides and lid by light from four banks of fluorescent ceiling lights in the experimental room. These lights were relay controlled and turned on automatically at the beginning of the session and off at the end. Ventilation was provided by air spaces in the top and bottom of the chamber. The chamber was in a room separate from the one containing the programming and recording equipment. The experimental room was 3.1 m by 3.1 m and was painted flat white to minimize reflections. A speaker and white noise generator provided a constant masking noise in the room. Room ventilation was through a ceiling register.

The response key measured 2.8 cm in diameter, and was located on the front panel with its center 36 cm from the right glass wall of the chamber and 27 cm from the aluminum mesh floor. The key was transilluminated by a red light during CS intervals and by a white light during the intertrial interval (ITI). It was darkened during reinforcer presentations. A force of approximately 0.18 N on the key closed a switch for electronically detecting key pecks. A feedback relay at the rear of the key provided a brief "click" following each switch closure.

The food aperture was located at the center of the front panel with its bottom edge 12 cm from the mesh floor. It was continuously illuminated by two SL-313 bulbs in series with a 3352-ohm resistor, except during feeder presentations when the resistor was isolated from the circuit. Thus, the intensity of the feeder light increased during feeder presentations. Reinforcement consisted of 3-s access to the food hopper, which contained Purina Racing Pigeon Checkers. During the reinforcement interval the keylight was off and the feedback relay on the key did not operate.

Two video cameras were directed toward the two glass walls of the chamber. The cameras were connected to an electronic video-acquisition module that computed, at $\frac{1}{30}$-s intervals, the spatial coordinates of the center of the highest dark region scanned by the cameras. The XZ coordinates were computed from the output of one camera, and the Y coordinate from the other. Since each bird's head was blackened, the head was the only dark area in the white and brightly illuminated chamber. Thus, the video-acquisition module computed changes in the position of a hypothetical dark point on the pigeon's head in three dimensional space as the bird engaged in key pecking and other activities in the chamber. The chamber was turned at an angle of 15° to the cameras to prevent interference from the aluminum frame of the chamber, excluding from view three narrow segments of the periphery of the chamber.

The video-acquisition module was connected to a Cromemco® Z-2D microcomputer, which was programmed to control experimental sessions, to average incoming data in blocks of three (one data point for every ⅒ s), and to store these data on floppy disks for later analysis. Graphed data were displayed on a CRT screen and printed by an Epson dot-matrix printer. Both cameras were connected to a television monitor, and a selector switch permitted visual observation from either camera throughout each session. For a block diagram of the system, see Pear and Eldridge (1984, Figure 1, p. 461).

### *Procedure*

*General experimental procedures.* Sessions were conducted 7 days per week at approximately the same time each morning until Day 24, when running time was shifted 3 hr later in the day where it remained for the rest of the study. Each autoshaping or omission training session was terminated after 60 trials. Baseline sessions were terminated after 1 hr. Food presentation time was excluded from calulations of session time and from all data analyses. Visual observations were made of each bird throughout most sessions to aid in analysis of the data produced by the automated tracking system. The observer (G.D.E.) recorded a brief verbal description of the bird's behavior during each CS, ITI, and feeder presentation during these sessions.

*Preliminary training.* Prior to the baseline sessions, the birds were magazine trained. They were placed in the chamber with the food hopper raised and the feeder aperture brightly illuminated. Once the bird had approached the raised hopper and consumed grain for approximately 20 s, the hopper was repeatedly raised and lowered at varying intervals independently of the bird's behavior. This continued until the bird approached and consumed food within 3 s for 10 consecutive trials. The feeder light was bright only when the hopper was raised; at all other times it was dim. The keylight was never illuminated during magazine training.

*Experimental design.* Bird 5052 was exposed to two baseline sessions, nine sessions of autoshaping, 12 sessions of omission training, and a final 30 sessions of autoshaping. Bird 1134 received two baseline sessions, seven sessions of autoshaping, 30 sessions of omission training, and a final 12 sessions of autoshaping. Bird 6859 received two baseline sessions and 18 sessions of autoshaping. It was not exposed to the omission procedure because it did not peck the key during autoshaping. On Day 3 of autoshaping, feeder duration was increased from 3 to 4 s for Bird 6859, and remained at that value for all subsequent sessions.

During baseline sessions, the key was continuously illuminated white; there were no feeder presentations, and the feeder light remained dim. During autoshaping, the key was illuminated by a red light for a fixed period of 8 s, following which the key was darkened and the food hopper raised for the duration indicated above. Each pairing of red keylight (CS) and feeder operation constituted a trial. Trials were separated by a variable ITI with a mean of 60 s, and a range from 30 to 90 s. During the ITI, the key was illuminated by a white light. Pecks on the key, whether during the CS or during the ITI, had no programmed effect other than the "click" of the feedback relay. During omission training, CS presentations and ITIs were identical to those during autoshaping, but pecks on the key during the CS resulted in omission of the scheduled food presentation at the end of the 8-s CS interval. Neither onset of the next trial nor duration of the programmed ITI was affected by food omission.

## RESULTS

Figure 1 plots over sessions for Birds 5052 and 1134 two dependent measures that are used frequently in studies of autoshaping and omission training: (a) number of trials with a key peck, and (b) response rate during the CS. For both birds, pecking at the CS began early during the first session of autoshaping. The number of trials with a key peck then rose quickly to maximum (Bird 1134) or near maximum (Bird 5052), while rate of key pecking in the presence of the CS increased more gradually. Following the introduction of the omission contingency, both number of trials with a key peck and rate of key pecking in the presence of the CS decreased for both birds. Both of these variables decreased to a lower level for Bird 5052 than for Bird 1134, despite the fact that 18 more sessions were conducted in this phase for the latter bird. For Bird 5052, the number of trials with a key peck decreased to fewer than six per session, and response rate in the presence of the CS stabilized at near zero during the last five sessions of the omission contingency. For Bird 1134, the number of trials with a key peck did not decrease below 30 per session, although key pecking in the presence of the CS stabilized at about eight responses per minute by the end of the omission phase. Following the reversal back to autoshaping (i.e., the removal of the omission contingency), both measures increased for both birds. For Bird 5052, however, the two measures reached a maximum lower than their levels during the first phase of autoshaping, and then declined. The final levels of these variables during the return to autoshaping were higher than during the last sessions of omission training but lower than during the first phase of autoshaping. Bird 1134 showed a rapid and complete reversal in both measures to levels seen during the first phase of autoshaping.

No across-session data are shown for Bird 6859, because, as mentioned in the Procedure section, this bird did not peck the key during any of the sessions of autoshaping. Within-session data are shown for this bird later.

A detailed examination of measures of response topography indicates three findings that are not apparent from the data described above: (a) great similarity in the patterns of responding between Birds 5052 and 1134, despite the disparity in the number of trials with a key peck and in response rate during the CS; (b) the persistence of high-rate back-and-forth head motions during the CS despite the decrease in key pecking as a result of the omission contingency for both birds; and (c) the similarity of the behavior of Bird 6859 to that of the other 2 birds during autoshaping despite the fact that this bird did not peck the key. Data supporting these conclusions are shown in subsequent figures. Some of the within-session data collected from Birds 5052 and 1134 were presented in Figures 2 and 3 of Pear and Eldridge (1984, pp. 462–463); however, those data were not from the same sessions as the data presented here.

Baseline data (i.e., data from initial sessions in which no feeder operations occurred) are not presented. After an initial period of agitated movement around the chamber in the first session of baseline, all birds preened or roosted for the remainder of the baseline sessions. There were no approaches to or pecks on the white key.

Figure 2 presents within-session data plotted as distance from the key over time for all phases for Birds 5052 and 1134. The top part of the figure shows data from the last session of the first phase of autoshaping, the next-to-last session of omission training (data from the last session in this phase could not be shown due to errors on the storage disk), and the last session of the second phase of autoshaping for Bird 5052. The lower part of the figure shows data from the last session of each phase for Bird 1134. For each bird, entire sessions are shown in the top graphs and portions of those sessions are shown below them. In some cases, data from the last part of a session are missing because of insufficient disk space to store the complete session. The portions shown in the lower graphs are indicated by the cursors at the bottom of each upper graph. Two-min segments from about the middle of each session were selected after careful scrutiny of the data from all sessions. These segments are representative of the stable patterns that developed by the end of each phase.

Absolute distance from the key, which was computed from distances on the X, Y, and Z axes, is indicated on the vertical axis, and session time is shown on the horizontal axis. Time during reinforcer presentations is not plotted. Key pecks are indicated by the vertical marks in the upper band at the bottom of each graph (if key pecks are close together, they appear as a solid dark area in the band). Presentations of the CS are indicated in the lower band at the bottom of each graph; in the lower, expanded graphs, CS duration is indicated by line length.

The graphs in the left column of Figure 2 show the distance-from-key patterns that developed during the first phase of autoshaping for both birds: (a) rapid approach to the red key at CS onset and key pecking throughout the CS, (b) withdrawal from the key and feeder following feeder presentations, and (c) repetitive excursions during the ITI. During the ITI Bird 5052 made repetitive excursions to and from the area of the white key, whereas Bird 1134 left the area of the white key and made repetitive pacing movements along the right glass wall of the chamber. Note the head movements which typically preceded pecks on the key during the CS for Bird 5052.

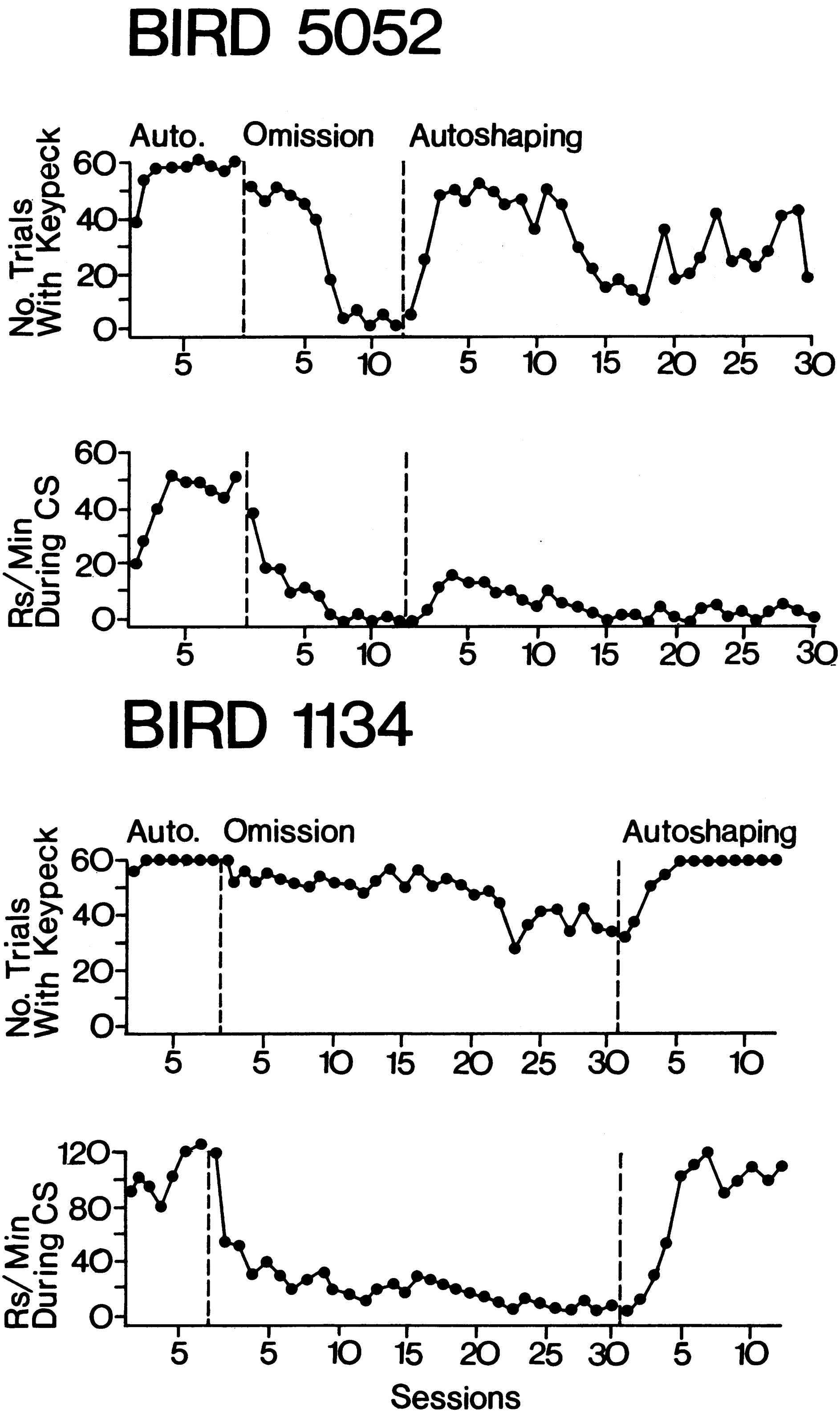
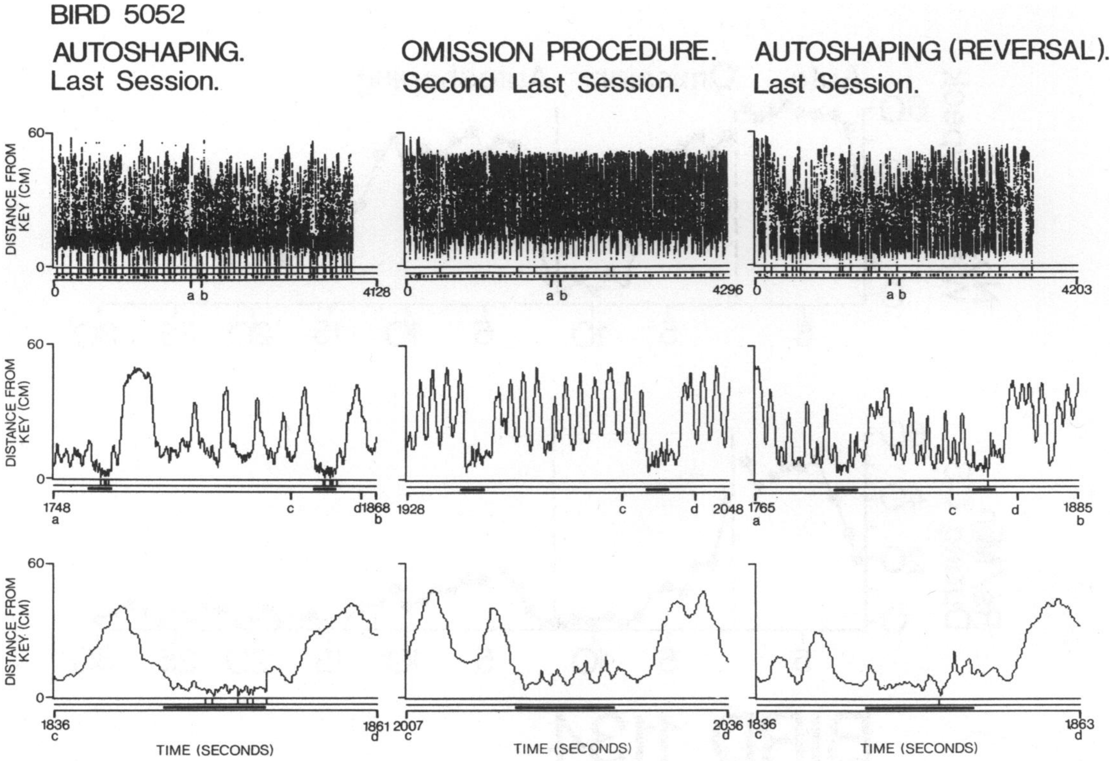
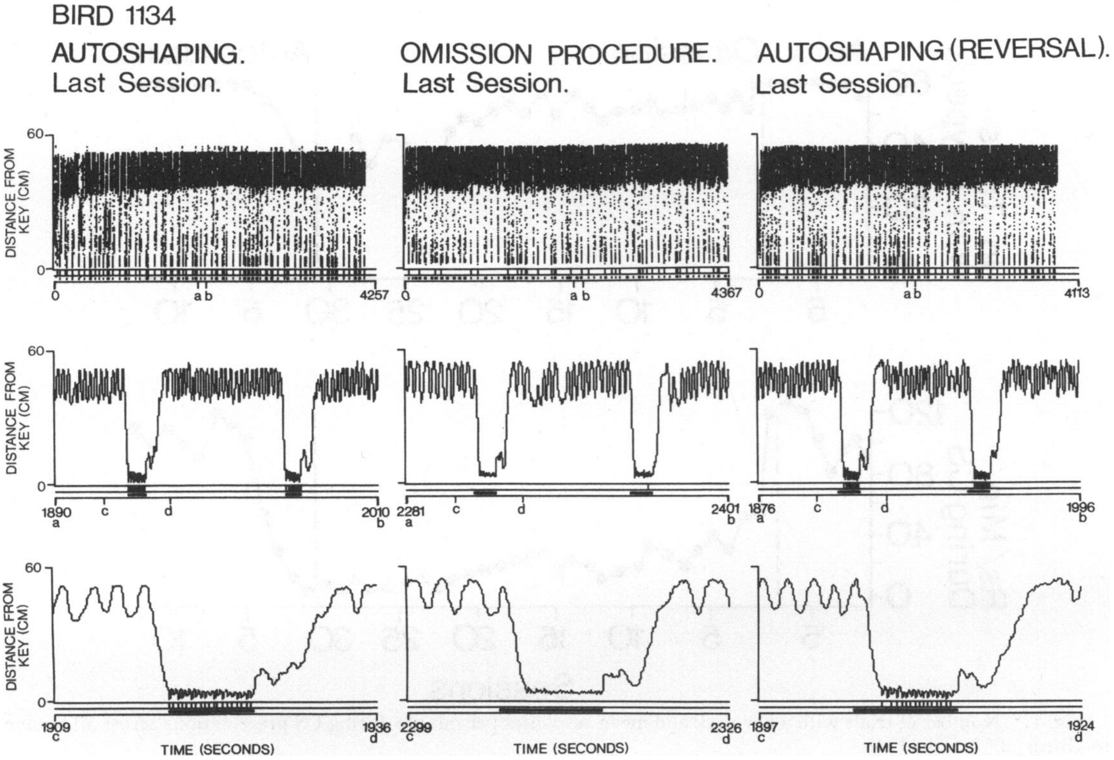


Fig. 1. Number of trials with a key peck and mean responses per minute during CS presentations across all sessions for Birds 5052 and 1134.


BIRD 5052
AUTOSHAPING. Last Session.
OMISSION PROCEDURE. Second Last Session.
AUTOSHAPING (REVERSAL). Last Session.
DISTANCE FROM KEY (CM)
60
0
0
a b
4128
4296
4203
1748 a
c
d 1868 b
1928
2048
1765 a
1885 b
1836 c
1861 d
2007 c
2036 d
1836 c
1863 d
TIME (SECONDS)


BIRD 1134
AUTOSHAPING. Last Session.
OMISSION PROCEDURE. Last Session.
AUTOSHAPING (REVERSAL). Last Session.
DISTANCE FROM KEY (CM)
60
0
0
a b
4257
4367
4113
1890 a
c
d
2010 b
2281 a
2401 b
1876 a
1996 b
1909 c
1936 d
2299 c
2326 d
1897 c
1924 d
TIME (SECONDS)

The graphs in the center column of Figure 2 show the distance-from-key patterns that developed during omission training for both birds. These patterns were (a) rapid approach to the key at CS onset, (b) back-and-forth head movements in the region of the key during the CS even though few key pecks occurred, and (c) ITI patterns that were similar to ITI patterns during the preceding phase.

The graphs in the right column of Figure 2 show the patterns that developed during the reversal to autoshaping. The pattern of rapid approach to the key at CS onset was maintained for both birds. For Bird 5052, the omission pattern of approaching the CS and making head movements that did not activate the key persisted throughout the reversal to autoshaping. In contrast, Bird 1134 generally contacted the key by the end of the reversal. A comparison of the graphs in Row 1 of Figure 2 indicates that Bird 5052 spent more time in the immediate area of the key during the ITI in both autoshaping phases than during omission training. Bird 1134 spent virtually no time in the immediate area of the key during the ITI in all phases, as shown in Row 4 of Figure 2.

Figures 3 and 4 present overhead (Y vs. X) plots and front elevations of the feeder wall (Z vs. X) for sessions corresponding to those illustrated in Figure 2 for Birds 5052 and 1134, respectively. The overhead plots are shown in the top two rows and the front elevations in the bottom row of each figure. For all overhead plots and front elevations, the key and feeder are indicated by "k" and "f," respectively. The broken lines on the overhead plots indicate areas of the chamber not visible to the cameras for the technical reason described earlier. The graphs in Figure 3 show data for the last session of autoshaping, the next-to-last session of omission training, and the last session of the reversal to autoshaping for Bird 5052. The graphs in Figure 4 show data for the last session of each phase for Bird 1134. The top row of each figure shows overhead plots of the entire session; for these plots, 30 data points are averaged for each discrete point plotted, yielding one point per second of session time. The second row of Figure 3 shows overhead plots of the CS periods encompassed by the cursors *c* and *d* in the second row for Bird 5052 of Figure 2, and the ITIs preceding those CSs. The second row of Figure 4 shows overhead plots during the CSs indicated by the cursors *c* and *d* in the second row for Bird 1134 of Figure 2, and the ITIs immediately following those CSs. For these plots the data points are averaged over $\frac{1}{10}$ s and the points are connected.

The density of the dark areas in the overhead plots in Figures 3 and 4 gives an indication of the proportion of time spent in various parts of the chamber. The high density areas indicate that Bird 5052 spent most of the session near the key and feeder during autoshaping (left column). This included approaches to the red key and to the white key. The lower density areas indicate circuiting of the chamber that occurred during the ITI. For omission training (center column), it is apparent that there are fewer approaches to the key and that those approaches are displaced to the left of the key. The ITI pattern of occasional circuits of the chamber with repetitive pacing along the right half of the feeder wall and the right glass wall can also be seen. For the reversal to autoshaping (right column) the similarity to patterns from the previous two phases is apparent. Note that the bird spent much more time in the area of the key than it did in the preceding omission phase. In addition, displacement of approaches to the left of the key persisted although this is partially obscured in this figure by the increased activity in the area of the key. The ITI pattern consisted of repetitive pacing along the feeder wall and the right glass wall, with frequent approaches to the area of the key and occasional circuits of the chamber.

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Fig. 2. Distance-from-key over time during a session at the end of each phase for Birds 5052 and 1134. For Bird 5052, the final sessions of both phases of autoshaping are shown, along with the second-to-last session of omission training. For Bird 1134, the last session of each phase is shown. All graphs show distance of the bird's head from the key, where each point is an average of three consecutive data points sampled at $\frac{1}{30}$-s intervals. Key pecks are indicated by vertical lines in the upper band below each of these graphs. CS presentations are indicated in the lower band. Data from the entire session are shown in the top row for each bird. Each graph in the other rows shows an expansion of the regions indicated by cursors in the graph immediately above.

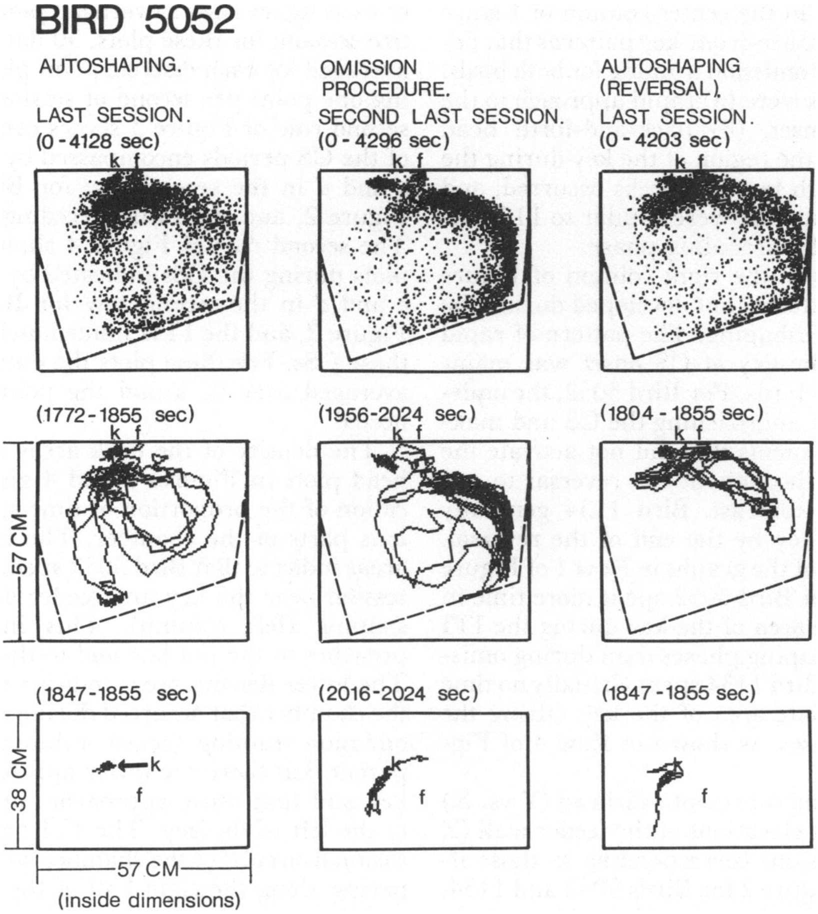


Fig. 3. Y versus X and Z versus X views during the sessions shown in Figure 2 for Bird 5052. The positions of the key and feeder are indicated by "k" and "f." The broken lines in the Y versus X plots indicate regions that were not visible to the cameras. Panels in the top row show successive locations of the bird's head as seen from above, during the entire session, with individual points representing data averaged over 1 s. The second row of panels shows the CS encompassed by cursors *c* and *d* and the preceding ITI in the second row from Figure 2. Points in these panels are averaged over $\frac{1}{10}$ s. The third row of panels shows a Z versus X view of the path of the bird's head during the CS encompassed by cursors *c* and *d* in Figure 2.

The overhead plots for Bird 1134 in Figure 4 show a repetitive pattern of pacing along the right glass wall of the chamber during the ITI, and approach to the key only at CS onset. These patterns were consistent across all phases.

The Z versus X plots (bottom rows) in Figures 3 and 4 indicate head movements made along the front wall during the CS encompassed by cursors *c* and *d* in Figure 2. The Z versus X plot of the first exposure to autoshaping for Bird 5052 shows that the bird's head remained in the immediate vicinity of the key during the CS. The plots in the center and right columns show that the bird's head was displaced to the left of the key during the CS in omission training and during the reversal to autoshaping. Visual observations indicated that the pigeon made pecking-like movements down the wall from the left side of the key to the floor of the chamber during CSs in these latter two phases. At least some of these back-and-forth head movements resulted in pecks on the wall as indicated by chipped areas in the paint following sessions.

The Z versus X plots for Bird 1134 (Figure 4) show the approach to the key at the onset of the CS and head movements in the immediate area of the key throughout the CS for all phases. Visual observations indicated that pecks

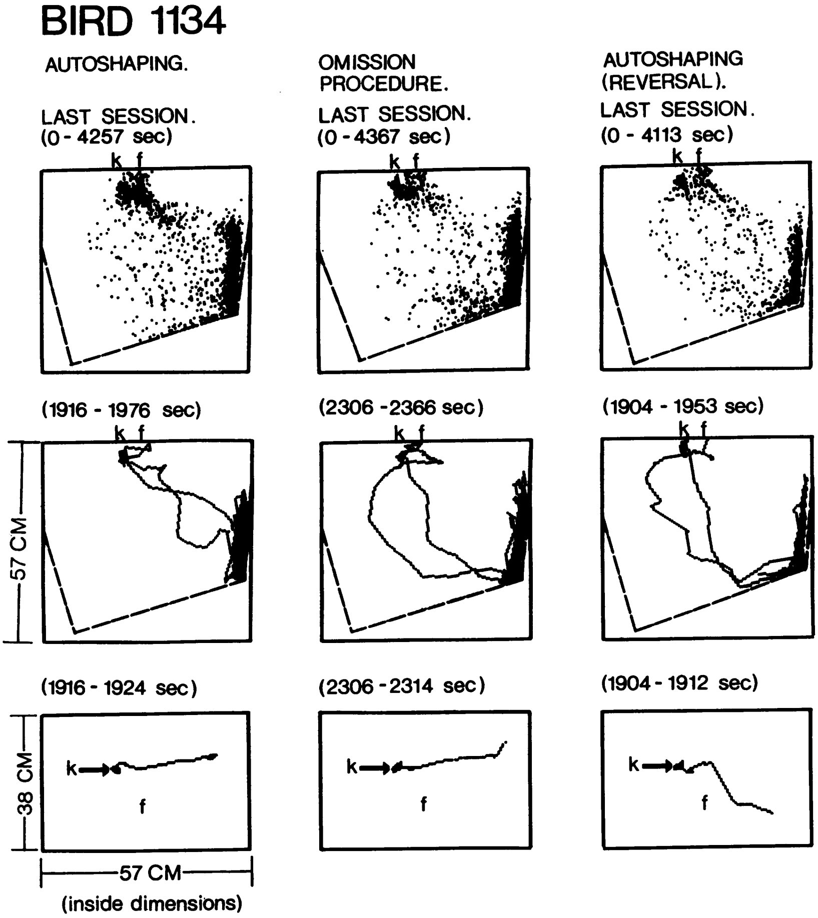
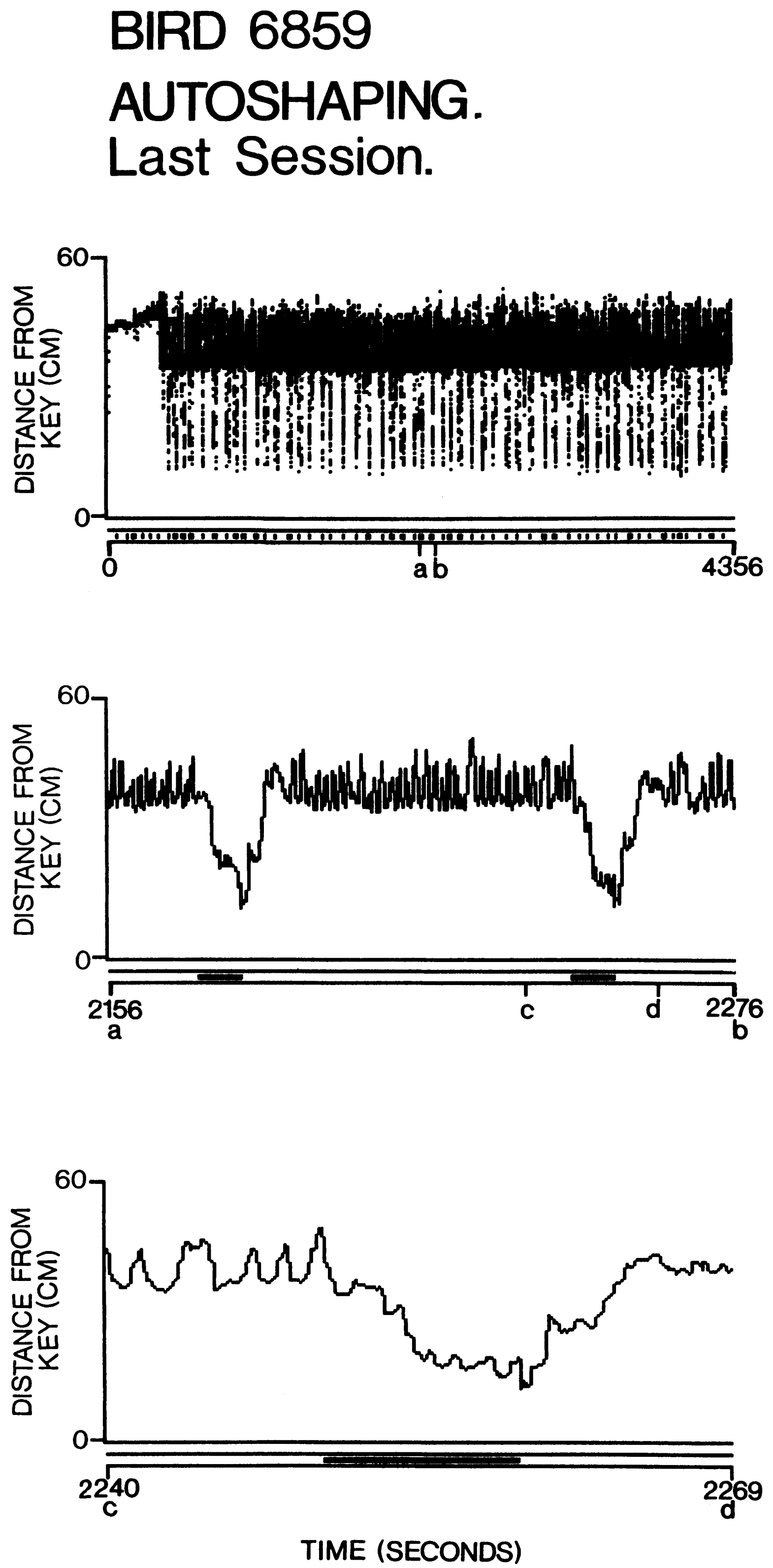


Fig. 4. Y versus X and Z versus X views during the sessions shown in Figure 2 for Bird 1134. The positions of the key and feeder are indicated by "k" and "f." The broken lines in the Y versus X plots indicate regions that were not visible to the cameras. Panels in the top row show successive locations of the bird's head as seen from above, during the entire session, with individual points representing data averaged over 1 s. Panels in the second row show the CS indicated by *c* and *d* and the following ITI in the second row from Figure 2. Points in these panels are averaged over $\frac{1}{10}$ s. The third row of panels shows a Z versus X view of the path of the bird's head during the CSs encompassed by cursors *c* and *d* in Figure 2.

occurred on the red key during both phases of autoshaping and were displaced to the right rim of the key (resulting in paint damage) later in omission training.

Despite the apparent differences in omission performance between Birds 5052 and 1134 suggested by Figure 1, a comparison of response topography shown in Figures 2, 3, and 4, along with visual observations of the sessions, indicates that there was consistency in performance across the 2 birds. In each case, efficient omission performance (i.e., not pecking at the CS) occurred only after pecking had been displaced to some area around the key. Omission responding for Bird 5052 was probably more efficient because its pecks were displaced farther from the key, which meant that there was less likelihood of an "accidental hit." For each bird, approach and pecking-like movements in the area of the CS were maintained despite the omission contingency.

The fact that Bird 6859 did not peck the key during 18 sessions of autoshaping might have led to its being discarded as a conditioning failure had measures of its behavior been limited to trials with a key peck or a response rate above zero during the CS (i.e., the data shown in Figure 1). However, an examination of response topography during autoshaping for this bird indicates great similarity between its per-



BIRD 6859
AUTOSHAPING.
Last Session.

Fig. 5. Distance of the bird's head from the key for the last session of autoshaping for Bird 6859. Details are the same as for Figure 2.

formance and the response patterns of Birds 5052 and 1134 during autoshaping. By Session 7 of autoshaping, Bird 6859 had developed a stable pattern of behavior during ITIs and CSs, patterns that persisted throughout the remaining sessions of autoshaping, despite the fact that this bird never pecked the key. This is illustrated in Figure 5, which shows distance from the key across time during the last session of exposure to the autoshaping procedure. Data selected for this bird are representative of stable patterns during the last 12 sessions on that procedure. Note that Bird 6859 made increasingly close movements toward the region of the key during most CS presentations. Moreover, like the other 2 birds, it withdrew from the area of the key and the feeder following feeder operations, and showed a repetitive pacing pattern throughout the ITI. Its data are therefore generally consistent with the data of the other 2 birds.

Figure 6 reveals further details concerning the performance of Bird 6859. The top graph of Figure 6 shows an overhead plot of the entire session shown in Figure 5; the middle graph shows an overhead plot of the CS period encompassed by the cursors *c* and *d* in the second row of Figure 5 and the preceding ITI. The bottom graph shows a Z versus X plot of that CS period alone. It can be seen from this figure that the ITI pattern consisted of pacing along the right glass wall of the chamber, similar to the pattern shown by Bird 1134. At CS onset, the bird rapidly approached the front wall of the chamber and made repetitive head thrusts toward the key throughout the duration of the CS. These thrusts were at key height, as indicated by the Z versus X plot. As described earlier, the tracking system detected the highest dark point in the chamber; therefore, the points plotted in Figure 6 represent the position of the top of the bird's head and not the beak. Visual observations indicated that the bird's head remained parallel to the front

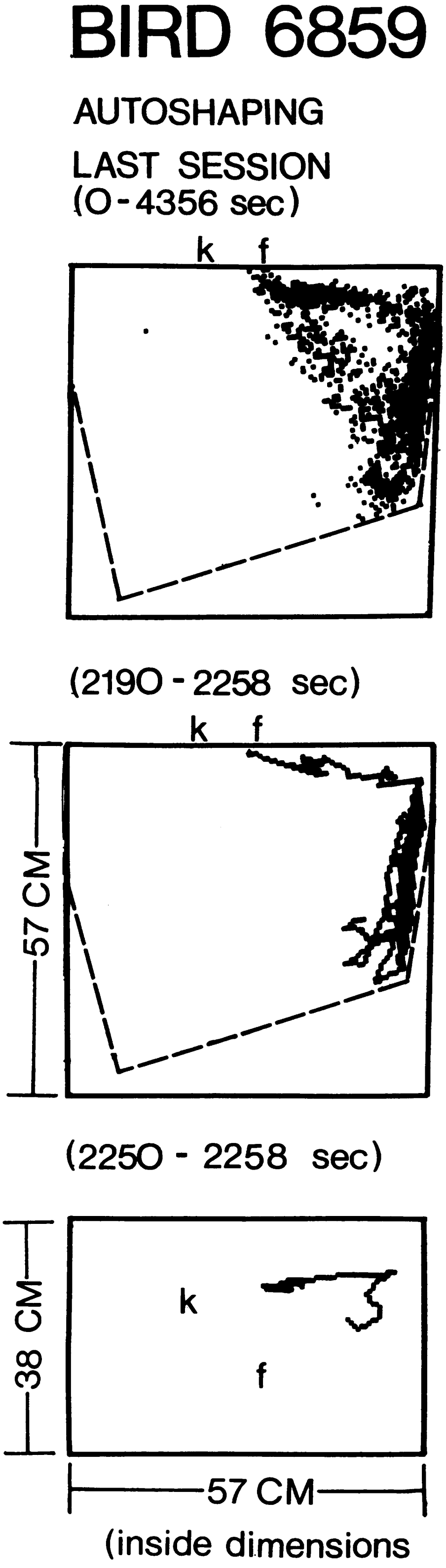


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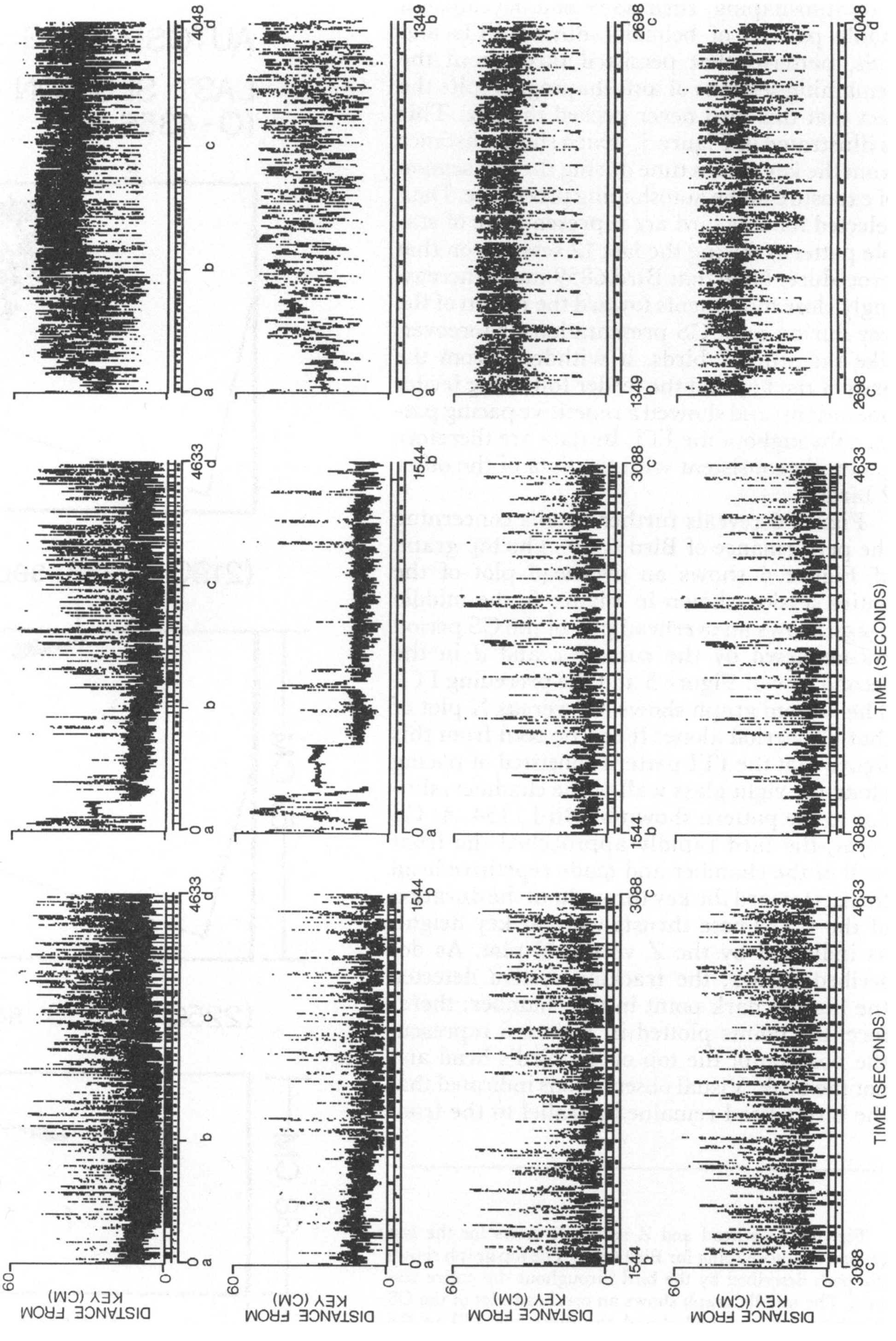
Fig. 6. Overhead and Z versus X views for the last session of autoshaping for Bird 6859. The top graph shows the path described by the bird throughout the entire session. The middle graph shows an overhead plot of the CS encompassed by *c* and *d* and the preceding ITI in the middle panel of Figure 5. The bottom graph shows a Z versus X view for that same CS. All other details are the same as for Figure 3.


BIRD 1134
AUTOSHAPING.
First Session.
BIRD 5052
AUTOSHAPING.
First Session.
BIRD 6859
AUTOSHAPING.
Third Session.
DISTANCE FROM KEY (CM)
60
0
a
b
c
d
0
1544
3088
4633
1349
2698
4048
TIME (SECONDS)

wall of the chamber during the CS with the beak directed toward the key. Back-and-forth head movements brought the beak close to the key, although the top of the bird's head remained above the feeder. At CS offset, the bird consumed food from the feeder, and then moved away from the area of the key and feeder immediately at the start of the ITI.

Since topographical data on the moment-to-moment development of an autoshaped response have not been presented previously in the literature, such data are presented in Figure 7 for the 3 birds in this study. Distance-from-key data are shown for Session 1 for Birds 5052 and 1134 and Session 3 for Bird 6859. Bird 6859 remained at the back of the chamber and neither consumed any reinforcers nor made any approaches to the key during most of the first two sessions.

The left column of the figure shows distance-from-key data for Bird 1134. The main feature to note is the gradual development of excursions away from the area of the feeder and the key during the ITI. Bird 5052 (middle column) was similar to Bird 1134 in the gradual development of excursions away from the key and feeder during the ITI, but differed in that approach to the red key was more gradual and key pecking occurred later in the session. The right column shows data for Bird 6859. The ITI pattern for this bird developed less gradually than for the other 2 birds. Early in this session, Bird 6859 moved in an apparently haphazard manner around the chamber during the ITI. Abruptly, on Trial 20, a repetitive pattern of pacing the right glass wall of the chamber during the ITI appeared and persisted throughout all remaining sessions of autoshaping. Head movements toward the red key developed gradually (see especially the graph in Row 2), but never culminated in a key peck.

## DISCUSSION

The most striking feature of the data from this study was the demonstration of control exerted by the CS and ITI stimuli over approach to and withdrawal from the area of the key. Within a few pairings of the keylight and food during autoshaping, all subjects began to approach the red key immediately after its onset. On Days 1 and 2 of autoshaping, Bird 6859 missed all reinforcer presentations and did not approach the red key; however, on Day 3, after consuming reinforcers on only 15 trials, it began to orient and make head movements toward the key during the CS. These head movements gradually developed into approaches to the CS that persisted for the remaining 15 days of autoshaping. For Birds 1134 and 5052, the CS controlled pecking as well as approach to the key. For both birds, approach to the CS and pecking-like movements persisted despite the introduction of the negative contingency placed on key pecking during omission training. For all 3 birds, withdrawal from the area of the key and the feeder during the ITI developed early in autoshaping and persisted throughout all phases. Birds 1134 and 6859 made repetitive pacing movements along the right glass wall of the chamber during ITIs, and Bird 5052 combined pacing along the right feeder wall and right glass wall with occasional circuits of the chamber. This approach and withdrawal under the control of stimuli correlated with reinforcement and nonreinforcement, respectively, satisfies Hearst and Jenkins' (1974) definition of positive and negative sign-tracking; however, the pacing responses that occurred during the ITI stimulus indicate that something other than simple directionality away from the stimulus may be involved in negative sign-tracking.

A main issue addressed in this study was a description of changes in response topography during the CS that occurred when a negative response-reinforcer dependency was added to the autoshaping paradigm. As described earlier, during autoshaping both Birds 1134 and 5052 rapidly developed patterns of approach to the CS at its onset, with key pecks occurring throughout the CS. During the subsequent omission training, this pattern of approaching

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Fig. 7. The first session of autoshaping for Birds 5052 and 1134 and the third session of autoshaping for Bird 6859. Graphs in the top row show distance of the bird's head from the key for the entire session. Graphs in the lower rows show expanded views of successive thirds of the sessions indicated by *a*, *b*, *c*, and *d* in the top row. All other details are the same as for Figure 2.

the key at CS onset remained unchanged. However, both birds showed a temporary increase in abortive pecking directed at the CS and a decrease in key pecking during the CS. This increase in abortive pecking probably reflected sensitivity to changes in the response-reinforcer relationship. Another possibility is that the abortive key pecking was due to a decrease in reinforcement rate, because trials with a key peck were not followed by reinforcement. This latter alternative does not seem likely, however, because of the occurrence of further changes in response topography.

Abortive pecking was not an efficient omission topography because many pecks continued to contact the key, resulting in the omission of reinforcers. Within five sessions of omission training for Bird 5052, abortive pecking disappeared and was replaced by pecking-like movements directed toward the chamber wall to the left of the key. Over subsequent sessions, these movements shifted farther down the wall and away from the key during the CS, and the efficiency of omission performance increased until few, if any, reinforcers were omitted.

In contrast, Bird 1134 continued to make abortive pecks for 16 sessions despite receiving a maximum of 11 reinforcers in any one session. Similar to Bird 5052, however, abortive pecking was eventually replaced by pecks at the right rim of the key. This was a somewhat more efficient omission topography; however, unlike Bird 5052, Bird 1134 did not shift the location of pecks farther away from the key in subsequent sessions, continuing instead to peck close to the key. This meant that key pecks still occurred frequently, resulting in omitted reinforcers.

These results support the findings of Barrera (1974), Woodruff and Williams (1976), and Williams and Williams (1969), who reported that pecking was maintained during omission training, but that pecks were redirected from the key to areas close to the key. Interestingly, Lucas (1975) reported that abortive pecking increased during omission training, and in the present study, both subjects displayed increased abortive pecking prior to redirecting pecks to areas around the key.

Lucas (1975) and Wessells (1974) reported that an omission contingency suppressed only that component of behavior which it contacted. When an omission contingency was placed on key pecking, key pecking decreased and orientation and approach to the CS remained. When the omission contingency was expanded to include approach patterns, approach decreased and orientation to the CS remained. In the present study, approaches to the CS occurred immediately at CS onset in all phases. The fixed-trial procedure, in which reinforcers are delivered or omitted only at the end of the 8-s CS, meant that approaches to the key were removed in time from the negative response-reinforcer contingency. Therefore, the contingency should have had less effect on behavior occurring early in the CS (i.e., approach to the key), and a greater effect on behavior occurring late in the CS (i.e., pecking).

During the ITIs for both Bird 5052 and Bird 1134, frequent key pecking occurred early in the first exposure to autoshaping, but rapidly declined to zero. Following the reduction in key pecking during the ITI, repetitive patterns of behavior developed that included withdrawal from the key and feeder following feeder operations. This also occurred with Bird 6859, which never pecked. The white keylight, which was correlated with nonreinforcement, can be considered an inhibitory stimulus (Hearst, 1972). Therefore, the reduction in key pecking and withdrawal from the key during the ITI may illustrate inhibitory control as described by Hearst and Jenkins (1974) and Wasserman, Franklin, and Hearst (1974). It is also interesting to note the similarity of the ITI pattern of behavior that occurred in this study and the wall-related behavior observed by Innis, Simmelhag-Grant, and Staddon (1983), and by Timberlake and Lucas (1985) on fixed-time schedules of reinforcement. This suggests that similar processes may be involved in these phenomena.

The results of this study demonstrate the usefulness of a behavior tracking system in documenting the development of autoshaped key pecking and other behavioral effects of the autoshaping procedure. In addition, the results suggest that autoshaped key pecks are sensitive to and modifiable by their consequences. Autoshaped responses appear to be under the joint control of stimulus-reinforcer and response-reinforcer relationships.

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