

*"AUTOMAINTEANCE": THE ROLE OF
REINFORCEMENT¹*

STEVEN R. HURSH², DOUGLAS J. NAVARICK²,
AND EDMUND FANTINO

UNIVERSITY OF CALIFORNIA, SAN DIEGO

A key was illuminated on the average of every 30 sec for a duration of 6 sec and this was followed by food presentations. When key pecks in the presence of the light produced immediate access to grain (autoshaping procedure) pigeons were likely to peck. When pecks terminated the keylight but prevented access to grain (automaintenance procedure) pigeons were much less likely to peck. Seven of 12 pigeons failed to develop responding during the automaintenance procedure. Four of the five pigeons that responded during the automaintenance procedure were exposed to a procedure in which responses could not immediately terminate the light. Three of the four ceased to respond during optimal automaintenance conditions, suggesting that the response-dependent offset of the keylight had been reinforcing their pecking. Responding during the automaintenance procedure was eliminated for a fifth pigeon by eliminating the contiguity of light-offset and food-onset on those trials in which the pigeon did not peck. These results suggest that: (1) automaintenance (unlike autoshaping) is not an effective procedure for reliably generating responding; (2) responding that does occur during the automaintenance procedure is reinforced by the response-dependent offset of the keylight.

Williams and Williams (1969) demonstrated conditions that sustain pecking even when pecking prevents food presentations. In their procedure (called the automaintenance procedure), illumination of a response key consistently terminated with the presentation of grain. A peck on the lighted key darkened the key and terminated the trial without grain (response-dependent non-reinforcement). Pecks frequently occurred on these trials. The automaintenance procedure is a modification of an automated shaping procedure developed by Brown and Jenkins (1968) called autoshaping, in which a peck during a trial immediately produced grain instead of terminating the trial without grain. The sustained pecking under these conditions was apparently maintained by food reinforcement. Since food presentation was withheld during the automaintenance procedure, Williams and Williams (1969) argued that the occurrence of pecking

"demonstrates that a high level of responding does not imply the operation of explicit or even adventitious reinforcement (p. 520)".

This conclusion may be overstated because the automaintenance procedure does not eliminate all potential sources of reinforcement. For example, each response immediately turns off the keylight. Light offset may be reinforcing since, on trials when pecks do not occur, light offset immediately precedes food reinforcement. Light offset may thus be a conditioned reinforcer maintaining responding during the automaintenance procedure. It is also possible, as Herrnstein and Loveland (1972) suggested, that stimulus change—such as light offset—may be reinforcing when food is available quite apart from any conditioned reinforcement effect.

If either of these analyses is correct, imposing a delay between pecks and light offset should reduce or eliminate responding, since long delays of reinforcement maintain less responding than short delays (Chung and Herrnstein, 1967; Dews, 1960). Further, if the pairings of light offset and grain makes light offset a conditioned reinforcer, then elimination of this relationship should also reduce responding. Specifically, one condition in the present experiment replicated a procedure used with two subjects by Schwartz (1972) in

¹This research was supported by NIMH Grant 20752-01 to the University of California, San Diego. Reprints may be obtained from Steven R. Hursh, Department of Experimental Psychology, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D.C. 20012.

²During this research, Steven R. Hursh and Douglas J. Navarick were NIMH Predoctoral Fellows. Navarick is now at California State University, Fullerton.

which the keylight co-terminated with the magazine cycle. In other words, offset of the keylight was paired with the *termination* of food presentation, rather than with its onset. Schwartz found that pecking persisted under these conditions; on the basis of these data and those from two birds on a similar procedure, Schwartz rejected an explanation of automaintenance in terms of "the artifactual presence of conditioned reinforcing stimuli." The present experiments further evaluate the role of conditioned reinforcement while also examining the effects on automaintenance of delaying light offset.

EXPERIMENT I

The purpose of the first experiment was to evaluate the proposition that automaintenance could be eliminated by imposing a delay between responses and the offset of the keylight.

METHOD

Subjects

Four White Carneaux pigeons (7777, 6278, 4835, and 6392) with varied histories of key pecking were maintained at approximately 80% of their free-feeding weights.

Apparatus

The experimental chamber was a modified two-key Gerbrands Co. chamber (Model-2K) measuring 12.25 in. (31.12 cm) by 10.88 in. (27.62 cm) by 11.38 in. (28.89 cm). The left keylight and the houselight were G.E. #1829 bulbs operated by 28 V dc. The right key was never illuminated. The left key was mounted 8.38 in. (21.27 cm) above the floor and 2.38 in. (6.03 cm) from the left wall. The key could be operated by a minimum effective force of 15 g (0.15 N). The solenoid-operated grain hopper was centered at the base of the front wall. During grain presentations, which lasted 4 sec, the houselight and keylight were turned off and the hopper was illuminated with white light. The chamber was covered with a plywood shell and white noise masked extraneous sounds; the control and recording equipment was located in an adjacent room.

Procedure

The four pigeons were exposed initially to the automaintenance procedure. Each daily

session consisted of 50 presentations of the white keylight. If no peck on the key was registered in 6 sec, the keylight was turned off and the food magazine was operated. If a peck occurred before 6 sec elapsed, the keylight was immediately turned off, but the food magazine was not operated. Trials were separated by an intertrial interval that averaged 30 sec and ranged from 3 to 180 sec. During the intertrial interval, pecks were recorded but had no scheduled consequences and the houselight was illuminated. Sessions were conducted seven days a week.

The subsequent conditions of the experiment for each subject depended upon its results in this first condition. Two subjects, Birds 7777 and 6278, were next exposed to a modified automaintenance procedure. After any response to the lit key, the offset of the keylight and the start of the intertrial interval were delayed for 2 sec. This imposed 2 sec between any response and the end of the trial (trial-offset-delay, or TOD procedure). Following this condition, the delay was removed and the initial condition was replicated.

The responding of Birds 4835 and 6392 was not maintained in the automaintenance condition. These birds were exposed to several sessions of continuous reinforcement (CRF) followed by additional sessions with the automaintenance procedure in an attempt to generate responding. Under one CRF procedure, the key was continuously white and any key peck throughout the session delivered 4-sec access to grain. Sessions lasted until there were 50 food presentations. Under a second CRF procedure ("trial CRF"), the key was lit 50 times throughout the session for 6 sec and any peck produced grain and terminated the trial. If 6 sec elapsed without a peck, the trial terminated without grain. The order of conditions and the number of sessions in each are included in the Results section (Figure 1).

RESULTS

Figure 1 summarizes the data. Birds 4835 and 6392 did not acquire automaintenance. Responding was observed only during the first sessions and may have resulted from their prior key-pecking histories. The CRF procedures produced and sustained reliable responding with these subjects. Reinstatement of the automaintenance procedure nonetheless failed to maintain responding; responses occurred on

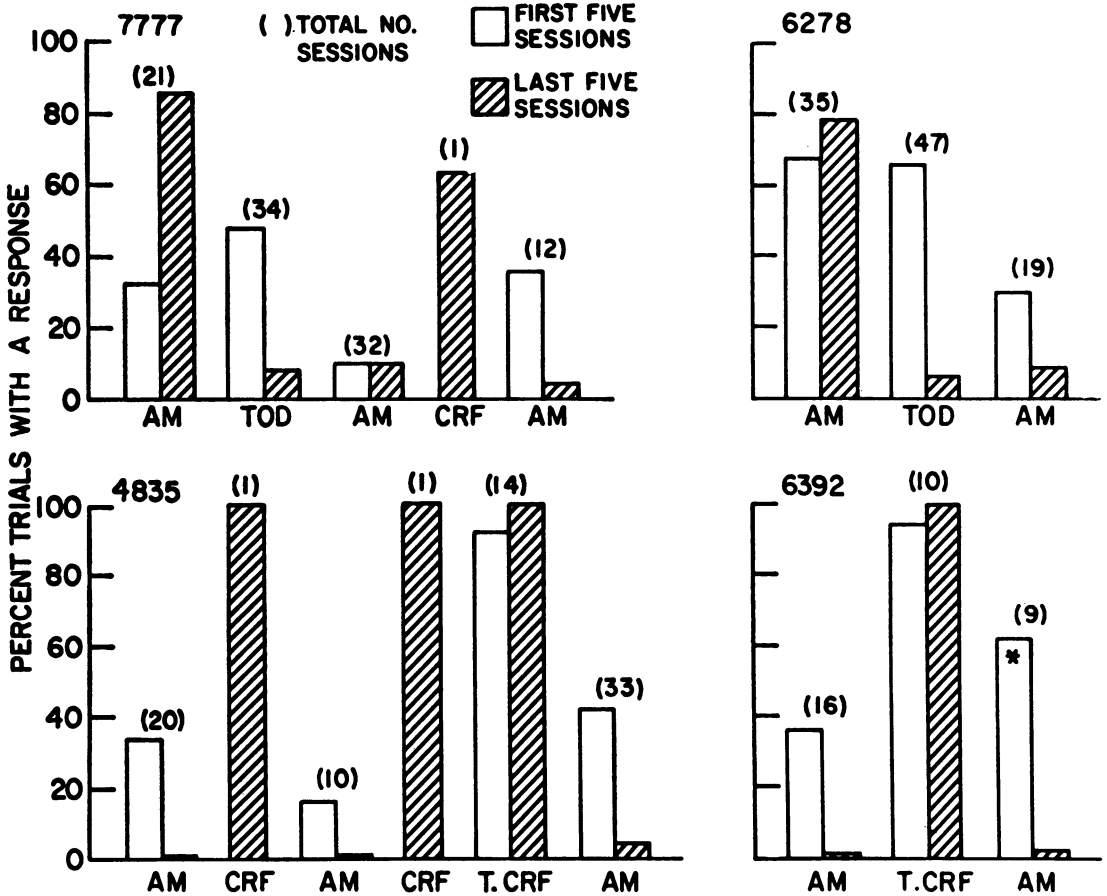


Fig. 1. Order of conditions and percentage of trials containing a peck for each bird in Experiment 1. Percentages are the means of the first and last five sessions of each condition. Asterisk (*) indicates mean of first four of nine sessions. "AM" refers to the automaintenance procedure; "TOD" refers to the "trial-offset-delay" procedure, and "CRF" and "Trial CRF" refer to continuous reinforcement procedures.

fewer than 20% of the trials within three sessions after a return to the automaintenance condition and occurred on fewer than 4% of the trials after 10 sessions.

The other two subjects acquired automaintenance, consistently responding on between 80 to 100% of the trials by the end of the automaintenance procedure. The delayed-trial-offset ("TOD") during the next condition produced a sharp decline in the number of trials containing pecks. By the end of this condition, fewer than 20% of the 50 trials included a key peck. Repetition of the original procedure without delay failed to reinstate responding to its original levels for each bird. Pigeon 6278 showed a partial and temporary recovery, which dissipated within about 15 sessions. Pigeon 7777 showed virtually no recovery except during Sessions 60 and 62. A

single session of trial CRF was carried out in the eighty-seventh session and occasioned many responses. Reinstatement of the automaintenance procedure following the CRF session resulted in responding on over one-third of the trials. Automaintenance declined in subsequent sessions, however.

EXPERIMENT II

Experiment I showed that for each of the two birds that acquired automaintenance, responding was eliminated by imposing a delay between responses and the offset of the key-light. However, since only two of the four subjects acquired automaintenance, eight additional subjects, six of which were experimentally naive, were exposed to the automaintenance procedure in Experiment II.

Alterations in the appearance of the chamber were gradually introduced in an effort to increase the probability of responses. When responding was observed, procedural changes were made to evaluate the variables maintaining the responding.

METHOD

Subjects

Three experimentally naive male, Silver King pigeons (SK1, SK2, SK3), three experimentally naive male homing pigeons (Y91, Y92, Y93), and two experienced male White Carneaux pigeons (6340 and 7778) were all maintained at 80% of their free-feeding weights.

Apparatus

The same chamber as in Experiment I was used except that in stages, the apparatus was progressively modified as follows: Stage A, the side walls were covered with black construction paper; Stage B, black paper on ceiling as well as on sides; Stage C, additional black paper on front and back panels; Stage D, in addition to the changes in Stages A to C, the houselight was removed; Stage E, a black metal plate was added around the response key to prevent the paper from shredding as a result of stray pecks.

Procedure

The naive pigeons were magazine-trained before the experiment. At the start of the magazine-training session, the hopper was raised and filled with grain. The subjects were allowed to eat for 20 sec before the hopper was lowered. The magazine was then operated at irregular intervals and the duration of the presentations was gradually reduced to 4 sec. After these food presentations, the pigeons were placed into either the automaintenance or the autoshaping procedure (see Figure 2). The automaintenance procedure was the same as during Experiment I. In the autoshaping procedure, key pecks during a trial not only terminated the keylight but also produced (rather than prevented) 4-sec access to grain. In the absence of a key peck, the two procedures were identical: the keylight terminated after 6 sec immediately followed by 4-sec access to grain. Subjects initially exposed to the autoshaping procedure were later switched to the automaintenance procedure when responding

stabilized. Since the subjects did not respond under the regular automaintenance procedure, the chamber was modified as indicated in the Apparatus section in an effort to increase responding.

Subjects that acquired automaintenance were exposed to modified versions of the automaintenance procedure. Some subjects were exposed to the TOD condition described in Experiment I. The length of the delay was varied from 2 to 10 sec (as noted in Figures 2 and 3). Other subjects were exposed to a procedure that continued the lighted key during any operation of the food magazine. This condition will be referred to as the "stimulus-overlap" condition (after Schwartz, 1972) since it was designed to remove the pairing of key-light offset and grain delivery. In one instance noted in Figure 3, the keylight was continued for 2 sec after the magazine presentation ("stimulus-overlap plus 2 sec"). In all other respects, this procedure was like the automaintenance procedure. Following either the TOD or the stimulus-overlap condition, most subjects were returned to the automaintenance procedure without the delay modifications.

RESULTS

The three subjects exposed first to the autoshaping procedure (SK1, SK2, and SK3) responded; pecks occurred on 92% of the trials on the average. None of them continued to respond when switched to the automaintenance procedure in an unmodified chamber. When returned to the autoshaping procedure, SK1 and SK2 recovered responding but SK3 did not. None of the four subjects (Y91, Y92, Y93, and 7778) exposed first to the automaintenance procedure in the unmodified chamber responded; pecks occurred on only 2.5% of the trials on the average. Three of the four (the exception was Bird 7778) acquired responding when exposed to the autoshaping procedure, emitting pecks on 77% of the trials. These three subjects (Y91, Y92, and Y93) were exposed to additional alternations of the automaintenance and autoshaping procedures. Figure 2 shows the results of these conditions for Y92 and Y93 as the mean per cent of trials with a response during the first and last five sessions of each condition. These patterns are representative of most subjects studied in the unmodified chamber; responding was maintained during the autoshaping

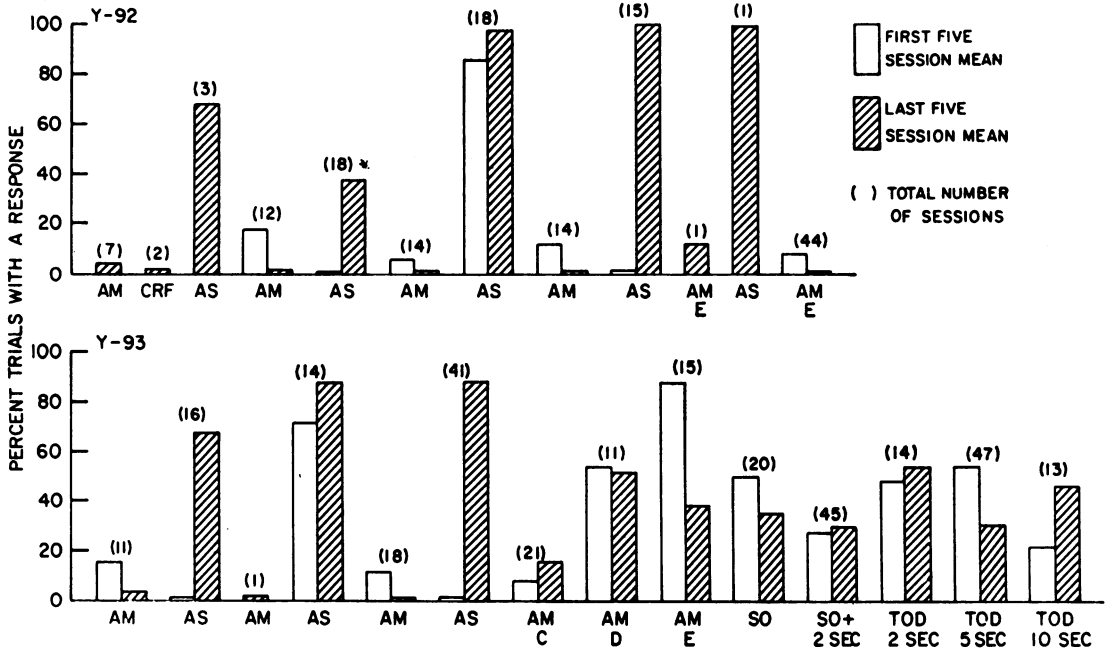


Fig. 2. Order of conditions and percentage of trials containing a peck for birds in Experiment 2. "TOD" refers to the "trial-offset-delay" procedure; "AS" refers to the autoshaping procedure and "AM" to the automaintenance procedure. "A", "B", "C", "D", and "E" refer to modifications to the chamber (see Apparatus section, Experiment 2). The last two sessions of the autoshaping (AS) condition indicated with the asterisk (*) had pecks on 96% of the trials.

procedure and was not maintained during the automaintenance procedure.

When the inside of the chamber was modified, as noted above, to eliminate reflections, three of six subjects exposed to the automaintenance procedure responded at a moderate level (Birds SK1, 6340, and Y93 but not Y92, SK2, or SK3). On the average, pecks occurred on about 50% of trials. The top panel of Figure 3 illustrates the effects of these changes as they were introduced in five stages with Bird SK1. When effective, each change produced an increase in automaintenance followed by a gradual decline. For SK1, responding levelled off at about half the trials with the chamber completely blackened except for the response key. Similar effects of modifications to the chamber with Y93 are summarized in the bottom panel of Figure 2. The third subject that responded during the automaintenance procedure, Bird 6340, was not exposed to the unmodified chamber.

The three subjects that acquired automaintenance were next exposed to the stimulus-overlap condition. For one subject, Bird SK1, responding was virtually eliminated. Removing the stimulus-overlap did not restore re-

sponding (see Figure 3). Bird 6340 showed some decreased responding during the stimulus-overlap condition; however, when the key-light was extended 2 sec after the magazine operation, responding gradually recovered (see Figure 3). Y93 showed no appreciable change during the stimulus-overlap conditions (see Figure 2). The day-to-day variability of responding by Y93 was very large; often the per cent of trials containing responses changed by over 40% over three sessions.

Since Birds 6340 and Y93 continued to respond under the automaintenance procedure, they were exposed to the TOD condition. The TOD of 2 sec temporarily decreased responding by Bird 6340; increasing the delay to 5 sec produced a large stable reduction in responding. Removing the TOD restored responding with Bird 6340, reversing the effect. These changes are shown in the bottom panel of Figure 3. Y93 showed a small decrease in responding with a TOD of 5 sec, but a delay of 10 sec did not produce a further decrease (see Figure 2).

In summary, of the eight subjects in this second experiment, three responded in the automaintenance procedure, after the chamber

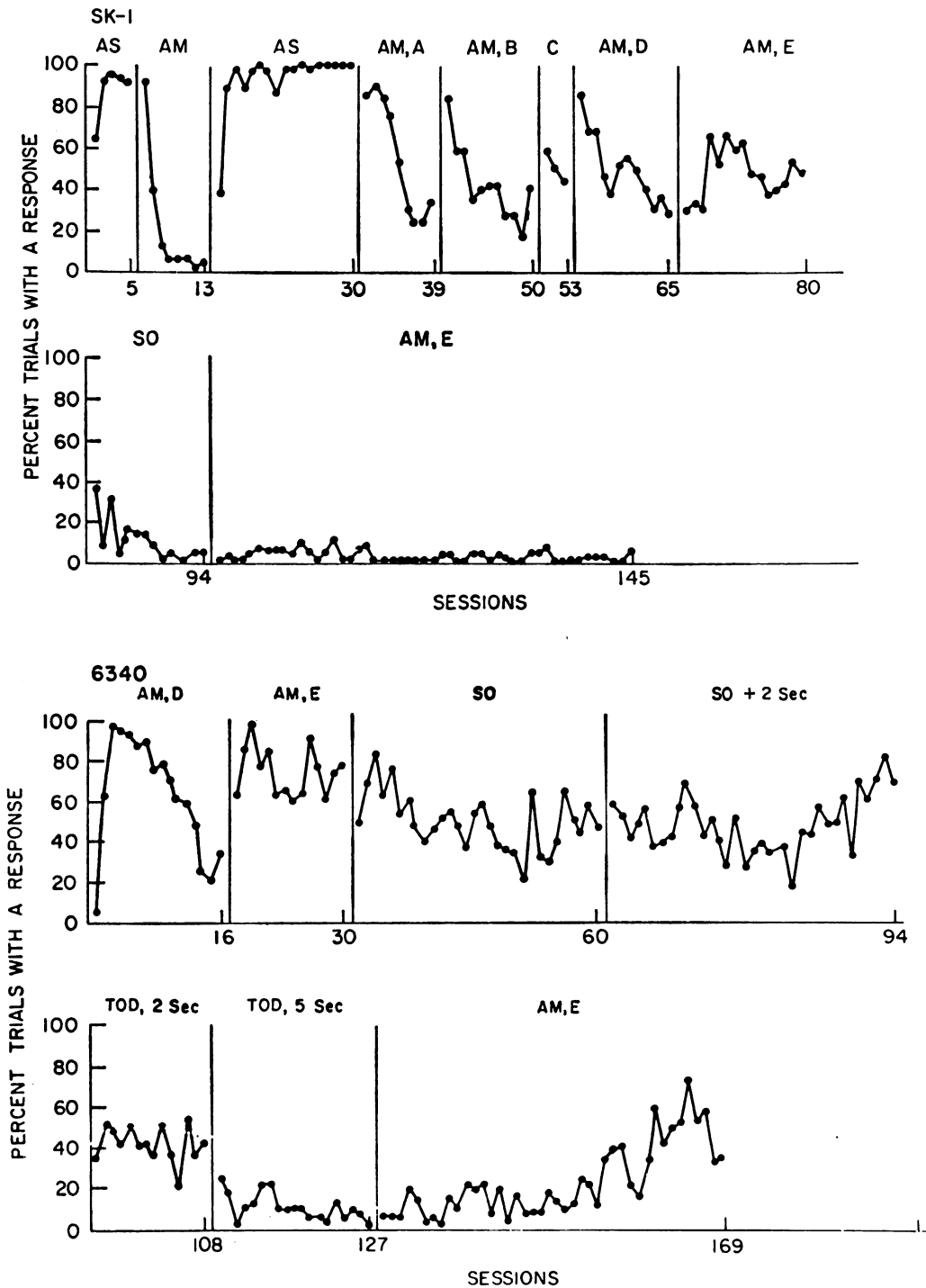


Fig. 3. Percentage of trials containing a peck as a function of sessions for Birds SK1 (top two panels) and 6340 (bottom two panels). The top two panels show the effects of introducing progressive changes in the physical characteristics of the chamber (see Apparatus section, Experiment 2). Elimination of automaintenance by the stimulus-overlap procedure (SO) is also illustrated. The bottom two panels show the elimination of automaintenance by the "trial-offset-delay" (TOD) procedure and subsequent recovery of responding upon reinstatement of the standard automaintenance procedure.

was blackened and the houselight was removed. One of these subjects stopped responding when offset of the keylight was not paired with the magazine operation, and an additional subject stopped responding when a delay was imposed between responses and the trial offset. One subject continued to respond on about half of the trials despite these procedural alterations.

GENERAL DISCUSSION

The main purpose of the present study was to determine whether or not automaintenance depended upon the reinforcing properties of light offset. The relations between light offset, responding, and grain presentations were manipulated in one or both of two ways: (1) responding turned off the light only after a delay of two or more seconds; (2) light offset was no longer correlated with food onset. These manipulations were successful in eliminating automaintenance in four of the five subjects that had acquired automaintenance. Seven other birds failed to develop automaintenance despite extensive experimental efforts to facilitate its acquisition. When the walls of the chamber were blackened, to eliminate reflections of the keylight, three subjects acquired automaintenance. For these subjects, the salience of the keylight appeared to be a critical factor in generating automaintenance. In all, then, only one of 12 subjects both displayed automaintenance and persisted in automaintenance in the face of the light offset manipulations. Thus, the results not only implicate the reinforcing properties of light offset in automaintenance, but also show that the automaintenance procedure, unlike the auto-shaping procedure, is not a reliable technique for generating responding. Moreover, of the four birds for which automaintenance was experimentally eliminated, only one (Bird 6340) recovered automaintenance, while a second (Bird 6278) exhibited a temporary recovery when the optimal automaintenance procedure was reinstated. Thus, the phenomenon is not only difficult to obtain but it is labile as well.

A portion of Herrnstein and Loveland's (1972) experiment involved a condition apparently equivalent to the automaintenance procedure. Their results resemble those of the present experiment rather than those of Wil-

liams and Williams. Although they do not report data for individual subjects, Herrnstein and Loveland's Table 5 shows that their median subjects (in each of seven groups) emitted a response on only 4% to 15% of the trials, well below the rates emitted by Williams and Williams' subjects. The ranges reported in the Table further suggest that many of Herrnstein and Loveland's subjects failed to acquire automaintenance altogether (*i.e.*, responded on fewer than 5% of the trials) as did seven of the 12 subjects in the present study.

While automaintenance is difficult to produce, it is nonetheless true that it sometimes occurs (in almost every case in the Williams and Williams study and in some cases in both Herrnstein and Loveland's study and in the present one). While there is no single explanation that can account for all obtained instances of automaintenance, the present results in conjunction with others suggest that reinforcing properties of the light offset account for most, if not all, instances of automaintenance. Herrnstein and Loveland suggested that "a combination of stimulus-change reinforcement and food reinforcement appear to account for the results, but only if it could be assumed that the presence of food in a procedure enhanced the reinforcing power of stimulus change, whether or not food was also dependent upon responding (page 369)". The Herrnstein and Loveland hypothesis is consistent not only with their results, but also with most of the results of Williams and Williams (1969), Schwartz (1972), and the present experiment.

In summary, the present results suggest that automaintenance is difficult to generate. When it does occur, it is probably maintained by the reinforcing effectiveness of response-dependent offset of the keylight: When response-dependent offset of the light is delayed, automaintenance declines. But even if keylight offset is reinforcing, why should it be more reinforcing than food even for the minority of the deprived pigeons? The answer may involve the fact that keylight offset is an immediate consequence of responding, whereas food presentation is delayed until 6 sec of non-responding have transpired. Immediately available small reinforcers are often preferred to delayed reinforcers that are much larger (Logan, 1965; Fantino, 1966; Rachlin and Green, 1972). If this interpretation is correct, automaintenance should be even more difficult to obtain if the

time required for non-responding were reduced well below 6 sec. In other words, with a 1- or 2-sec trial duration, food presentations dependent upon non-responding could occur after 1 or 2 sec instead of after the 6 sec or longer delays employed in previous studies of automaintenance (Williams and Williams, 1969; Schwartz, 1972; Herrnstein and Loveland, 1972), including the present one.

REFERENCES

- Brown, P. and Jenkins, H. M. Autoshaping of the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Chung, S. and Herrnstein, R. Autoshaping of the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 67-74.
- Dews, P. B. Free-operant behavior under conditions of delayed reinforcement. I. CRF-type schedules. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 211-234.
- Fantino, E. Immediate reward followed by extinction vs. later reward without extinction. *Psychonomic Science*, 1966, 6, 233-234.
- Herrnstein, R. J. and Loveland, R. J. Food-avoidance in hungry pigeons, and other perplexities. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 369-383.
- Logan, F. A. Decision making by rats: Delay versus amount of reward. *Journal of Comparative and Physiological Psychology*, 1965, 59, 246-251.
- Rachlin, H. and Green, L. Commitment, choice, and self-control. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 15-22.
- Schwartz, B. The role of positive conditioned reinforcement in the maintenance of keypecking which prevents delivery of primary reinforcement. *Psychonomic Science*, 1972, 28, 277-278.
- Williams, D. R. and Williams, H. Automaintenance in the pigeon: sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 511-520.

Received 12 March 1973.

(Final Acceptance 1 August 1973.)