*SOME VARIABLES AFFECTING RATE OF KEY PECKING
DURING RESPONSE-INDEPENDENT PROCEDURES
(AUTOSHAPING)¹*

CHARLES C. PERKINS, JR., WILLIAM O. BEAVERS,²
ROBERT A. HANCOCK, JR., PATRICIA C. HEMMENDINGER,
DENNIS HEMMENDINGER, AND JOHN A. RICCI³

KANSAS STATE UNIVERSITY

Rate of key pecking by pigeons subjected to response-independent procedures in which a stimulus on the response key preceded food presentation was investigated in eight experiments. Color and shape of the stimulus, duration of the stimulus, probability of food following the stimulus, duration of the intertrial interval, and duration of food presentation were varied separately and in combination. All variables studied, except color and shape of the stimulus, had a reliable effect on pecking rate, but some variables had stronger effects than others. Rapid key pecking may be obtained with a variety of response-independent procedures, as well as by response-dependent reinforcement. The results of experiments in which food is both dependent on key pecking and correlated with stimulus conditions are not representative of simple operant effects. Key pecking is an ideal response for studying the simultaneous operation of response-reinforcer and stimulus-reinforcer effects.

CONTENTS

- Experiment 1: Color and form of the stimulus
- Experiment 2: Stimulus duration
- Experiment 3: Proportion of the trials followed by food
- Experiment 4: Interaction of stimulus duration and proportion of trials followed by food
- Experiment 5: Duration of the intertrial interval (ITI)
- Experiment 6: Interaction of stimulus and ITI durations
- Experiment 7: Duration of food presentation
- Experiment 8: Duration of food presentation—additional data

Brown and Jenkins (1968) reported acquisition of the key-pecking response during a response-independent procedure in which il-

lumination of the key was followed by food regardless of what the pigeon did. They designated this phenomenon autoshaping. Key pecking that presumably had been established or maintained at least in part by a stimulus-reinforcer relationship (as distinct from a response-reinforcer relationship) had been previously reported from at least three laboratories (Jenkins, 1970; Meyers, 1958; Thomas and Caronite, 1946). However, in those earlier reports, all of the key pecking seems to have been attributed entirely to the response-reinforcer relationship.

Hearst and Jenkins (1974) reviewed the literature on sign tracking, the acquisition and maintenance of key pecking, and certain other approach and contact responses by Type S conditioning (Skinner, 1938). Therefore, a lengthy review here is unnecessary. It will suffice to note that it is well established that pigeons will peck a response key during a signal localized on the key before food (or some other reinforcer) is presented. Among the published findings are continued pecking of a stimulus on the key when the response prevents food delivery (Williams and Williams, 1969), when there are randomly spaced free-food deliveries during the stimulus but not in its absence (Gamzu and Williams, 1971, 1973), and when the stimulus is 30 or even

¹This research was supported by NSF Grant CB 27595 and NIMH Training Grant 5T01MH 08359. Experiments 7 and 8 were in partial fulfillment of RAH's requirements for a Master's Degree. Reprints may be obtained from Charles C. Perkins, Jr., Department of Psychology, Kansas State University, Manhattan, Kansas 66502.

²Now at Department of Psychology, Southern Methodist University, Dallas, Texas.

³Now at Viterbo College, La Crosse, Wisconsin.

120 sec long and terminates with food delivery (Ricci, 1973). There is also experimental evidence that autopecking tendencies, those key-pecking tendencies that result from the relationship between a stimulus and a reinforcer, play a major role in behavioral contrast (e.g., Redford and Perkins, 1974) and differential-reinforcement-of-low-rate (DRL) schedules (Hemmes, *personal communication*). There is every reason to expect that autopecking may also play a role in other procedures, such as chained schedules and successive discrimination problems, when the response studied is key pecking in pigeons.

The term autopecking is employed in this paper to designate key pecking that is established and/or maintained by response-independent (Type S) procedures. This term is similar enough to autoshaping to suggest the Brown and Jenkins' work, but avoids their strong emphasis on acquisition as distinct from maintenance. The term autopecking is also intended to suggest that any attempt to generalize findings to behavior other than the much-studied key-pecking response should be only a tentative working hypothesis until more relevant data are available. We are not as convinced that such pecking is representative of a large class of approach and contact behaviors as Hearst and Jenkins (1974) seem to be.

The present paper reports a series of experiments designed to explore the effects of several variables on rate of autopecking within a discrete-trial procedure with food presented at termination of a stimulus localized on the response key. In all cases, the conditions of lighting, etc., were optimal or near optimal for providing the localized stimuli required for high rates of autopecking (Wasserman, 1973). The variables studied were the specific stimulus employed (Experiment 1), duration of the stimulus (Experiment 2), the per cent of the trials on which food followed the stimulus (Experiment 3), the interaction of percentage of stimulus presentations followed by food and stimulus duration (Experiment 4), the duration of the intertrial interval (ITI) (Experiment 5), the joint effects of varying ITI and stimulus duration (Experiment 6), and duration of food presentation (Experiments 7 and 8). The order in which the experiments are reported differs from the order in which they were carried out.

GENERAL METHOD

Subjects

All pigeons were naive and served in only one experiment, except as noted for four subjects in Experiment 8. The birds were obtained from local dealers. Pigeons in Experiment 1 and some in Experiment 8 appeared to be Homers, all others appeared to be White Kings. All birds were maintained at 75% of free-feeding weights throughout.

Apparatus

Two standard, three-key Grason-Stadler test chambers (Model E 3125AA-3) with the side keys covered were used in Experiment 5. Single-key pigeon test chambers with inside dimensions of 32.7 by 38.7 by 31.1 cm were employed in all other experiments. The latter test chambers were constructed of plywood except for one wall, which was a metal panel on which the key and feeder were located. The interiors were painted with gray enamel. In the center of the ceiling was a translucent window, above which was a 7.5-W ac house-light. A Gerbrands response key was centered at one end of the box 23 cm above the floor. The opening to the grain feeder (Lehigh-Valley) was directly below the key and 3.7 cm above the floor. Stimuli were presented by means of Industrial Electronics Engineers' stimulus display cells with GE-44 bulbs in a 6.3-V ac circuit.

Sets of two or four boxes were several feet apart in the same room. All events in each set of two or four boxes were simultaneously controlled by the same tape reader and other control equipment. A set of birds refers to two or four subjects serving simultaneously in boxes in which events were arranged by the same control equipment. A white noise of approximately 80 dB measured inside the box masked sounds from other boxes and from the control and recording equipment in an adjoining room. A relay behind the response panel provided a click after each response, a peck on the key exceeding about 0.15 N. Counters rated as counting up to 25 counts per second were used for primary data collection, but print-out counters and/or event recorders were also used at times.

Procedure

Except as noted, all subjects received two days of feeder habituation with the key cov-

ered by tape. On the first day, the bird was trained to eat from the feeder by being held over it and then released and gradually adapted to shorter food presentations at longer intervals. On the second day, food presentations were provided at the same rate, frequency, and duration as during the training sessions that were to follow. All birds were observed on the last five food presentations of the second day. Training was initiated the next day for birds that ate on three of the last five food presentations. On the few occasions in which eating was not started and maintained on the first day, or the criterion of eating on three of the last five feeder presentations was not attained, that day's procedure was repeated the next day. In no experiment was food or any other stimulus except the feedback click ever dependent on the response. In each experiment, the houselight was on at all times except during food presentation (4 sec except as noted). Sessions were on successive days unless otherwise indicated.

EXPERIMENT 1

Experiment 1 determined if rate of autopecking would be affected systematically by the color, pattern, or brightness of the stimulus projected on the response key. The primary reason for studying these stimulus variables was methodological. Any within-subject design in which different stimuli are associated with different values of the variable(s) under study necessarily confounds stimulus differences with the variables of primary interest. If the specific stimulus employed has no effect on rate of autopecking, then the more efficient multiple-stimulus designs may be employed without counterbalancing to investigate the effects of other variables such as stimulus duration and the per cent of stimulus presentations followed by food.

METHOD

Subjects

Two groups each of four pigeons served.

Procedure

Both groups received identical training except for the stimuli on the key. For each group, five different 8-sec stimuli were each presented 60 times in a session and each stim-

ulus was followed by 4-sec feeder presentations on an unpredictable one trial in 10.

Other data (*e.g.*, from Experiment 3 below) suggested that if all stimulus presentations were followed by food, responding might approach maximum rate. Such a ceiling effect would tend to mask possible effects of color or pattern of the stimulus. Presumably, a more sensitive measure of the possible effects of stimulus attributes is obtained with conditions less conducive to the maximum rate of autopecking (*e.g.*, with food following only one stimulus in 10). The intertrial interval, the interval between food termination on food trials or stimulus termination on non-food trials and presentation of the next stimulus, was 60 sec. Six identical cycles of 50 trials were arranged during each session by use of looped tapes and eight-channel tape readers. The sequence of stimuli and of food and non-food trials was random within a 50-trial cycle, with the restrictions that each stimulus was presented 10 times and followed by food once and that no stimulus was presented more than twice in succession. Five different tapes were employed and the starting point for a tape differed from day to day so that the birds would not learn sequences. Thus, on each day a bird received 60 presentations of each of the five stimuli, six of which were followed by food, making a total of 300 trials and 30 food presentations. The 30 daily sessions each lasted 5 hr and 42 min.

For Group I, the five stimuli were uniform colors, white (W), blue (B), red (R), yellow (Y), and green (G); during the ITI, the key was dark. For Group II, the key was illuminated by a white light during the ITI and the five stimuli were no transillumination (N), red (R), yellow (Y), three black horizontal lines on a white background (L), and three black dots on the horizontal midline on a white background (D).

RESULTS

All birds started pecking the stimuli during the first or second session. By the fourth session, they were responding to stimuli at over half their rate in Sessions 21 to 30. There were no systematic changes in rate of pecking during stimuli for either group after about Session 16.

Table 1 shows pecking rate in responses per minute to each stimulus and during the

Table 1

Summary of performance on Sessions 21 to 30 of Experiment 1 for individual subjects and group means. All values are responses per minute. The stimuli are as follows: B = Blue, Y = Yellow, W = White, R = Red, G = Green, N = no transillumination, L = three black horizontal lines on a white background, and D = three black dots in a horizontal row on a white background. The intertrial interval (ITI) conditions were no transillumination for Group I and a white light for Group II.

Pigeon	Stimuli					All Stimuli	ITI (N)
	B	Y	W	R	G		
1	132	114	131	93	87	112	0.4
2	214	219	213	210	214	214	12.3
3	133	133	144	123	145	136	0.6
4	136	138	173	142	169	152	1.2
Mean Gr.	I	154	151	165	142	154	3.6

Pigeon	Stimuli					All Stimuli	ITI (W)
	N	R	Y	L	D		
5	140	153	160	143	136	146	7.9
6	180	178	205	201	179	189	3.8
7	35	31	30	9	29	27	0.5
8	166	162	153	154	149	157	1.6
Mean Gr.	II	130	131	137	127	123	3.5

ITI in Sessions 21 to 30 for each bird separately and mean rate for each group. As can be seen in Table 1, all but one bird averaged over 110 responses per minute to all stimuli. For every bird, rate during the ITI was less than one-fifteenth of the rate to any stimulus.

The mean rates to different stimuli within each group were remarkably similar. Individual birds did show some differences in rates to different stimuli. However, rate to different stimuli differed by a factor of 1.18 or less in five of the eight pigeons and by a factor greater than 1.52 only for the atypical bird (7).

So long as it was clearly different from the ITI condition, the specific color, pattern, or brightness of the stimulus had little or no effect on rate of autopecking at steady state. The lack of systematic rate differences between stimuli cannot be attributed to a ceiling effect. That is, the lowest rate to any stimulus was not so high that the bird could not respond at a reliably higher rate to other stimuli. That the measures were potentially sensitive to stimulus effects was demonstrated by the rate differences between stimuli within individual birds. Also, changes in rates from day to day (not shown) were too marked for the birds to be at their maximum at all times. For example, the mean rate to all stimuli during a session varied by a factor of 2 dur-

ing the last 10 sessions for Pigeon 2, the most rapid responder. The results of Experiment 1 indicate, therefore, that complete counterbalancing of stimuli is not required to determine the effects of other independent variables on autopecking rate.

EXPERIMENT 2

Experiment 2 determined the effect of stimulus duration on rate of autopecking.

METHOD

Subjects and Apparatus

Four naive pigeons served and the same four chambers and control equipment described in Experiment 1 were used.

Procedure

Throughout training, all birds were presented four different stimuli, yellow, green, blue, and red, which were of 4-, 8-, 16-, and 32-sec duration, respectively, during Sessions 1 to 54, and 32-, 16-, 8-, and 4-sec duration, respectively, during Sessions 55 to 67. Sessions were made up of 24 or 30 cycles within which each stimulus was presented once. During a session, each stimulus followed each other one equally often and the proportion of presen-

Table 2

Summary of changes in experimental treatments during experiment 2.

Sessions	Total Trials	Proportion of Food Trials	Intertrial Interval (sec)
1- 6	96	1/12	30
7	96	1/6	30
8- 9	120	1/6	30
10-36	96	1/6	30
37-46	96	1/6	120
47-54	96	1/6	30
Colors reversed and eight-day break			
55-67	96	1/6	30

tations of each followed by 4 sec of food was 1/12 or 1/6, as indicated in Table 2. Within the limitations implied, food presentation was equally probable on each trial within a session. Table 2 also shows the number of trials (stimulus presentations) per session and duration of the ITI.

RESULTS

Figure 1 shows the mean pecking rate for the four subjects to each of the 4-, 8-, 16-, and 32-sec stimuli during each session. Relationships apparent in Figure 1, which were also obtained for each bird individually are: (a) a lower rate of pecking to the 32-sec stimuli than to others, (b) an increase in pecking rate to 8-, 16-, and 32-sec stimuli when the ITI was increased from 30 to 120 sec, and (c) similar rates to stimuli of each duration at steady state with both color-duration combinations.

There were also some marked differences in response rates between subjects. Pigeon 4 responded to all stimuli at a rate less than half the mean rate for the other birds. Pigeon 2 responded only at very low rates typically (1 to 5 responses per minute) to the 32-sec stimulus, but pecked at a moderate or high rate to the other stimuli. On the other hand, ratios of the rates to different stimuli were seldom over three to one for Pigeons 1 and 3.

Pigeons 1, 2, and 4 usually made no responses during the ITI except during the first 4 sec. Only one of these birds exceeded seven such responses a session and that only in three sessions. However, Pigeon 3 responded a great deal during the ITI. The first 4 sec of ITI were excluded from measures of ITI

Fig. 1. Mean rate of responding in Experiment 2. Each curve shows the mean rate of responding for the four birds in Experiment 2 to each of the four stimuli during each session.

rate so that run-over responses initiated during stimuli would not affect the measures. Mean ITI rate for Bird 3 in Sessions 42 to 46, the last five sessions with the 120-sec ITI, was 10.8 responses per minute. In Sessions 63 to 67, its mean ITI rate was 25.8 responses per minute. While quantitative data are not available, casual observation indicated that its rate increased within ITIs.

To summarize, the rate of pecking was consistently lower to the 32-sec stimulus than to 4-, 8-, or 16-sec stimuli. Stimulus duration did not appear to affect rate of approach to steady state. The lack of an effect of color of stimulus that was found in Experiment 1 was also noted in this experiment.

EXPERIMENT 3

We have been able to find only three references in the literature on the effects of per cent of the stimulus presentations followed by food on autopecking. Hearst and Jenkins (1974) mention Peden's work in Hearst's laboratory in which autopecking was obtained with 50% and 25% reinforcement. Gonzales (1973) reported less autopecking with 25% than 100% reinforcement. Schwartz and Williams (1972) reported higher rates with food probabilities of 0.5 and 0.2 than with a probability of 1.0, and a still lower rate when $p = 0.05$. Experiment 3 determined how autopecking rate is affected by the per cent of the stimulus presentations followed by food.

METHOD

Subjects and Apparatus

Eight naive pigeons served and sets of two and four experimental boxes were employed.

Procedure

Each session consisted of 27 cycles. During a given cycle, each of five key colors was presented once, making a total of 135 trials. The order of stimulus presentations differed from cycle to cycle, providing an unpredictable sequence. The number of times a particular stimulus was followed by 4 sec of food in each session was either 27, 9, 3, 1, or 0. A tape reader with a continuous tape controlled presentation of all stimuli to a set of boxes simultaneously. Counters recorded the total number of responses to each stimulus, including the ITI during a session; the ITI was always 1 min. The color of the stimulus associated with each condition was partially counterbalanced across subjects. Duration of the stimuli was 8 sec for two pairs of birds. One pair was studied for 20 training sessions, the other for 30. Stimuli lasted for 20 sec for the other four pigeons, which received 30 training sessions followed by three sessions of extinction in which the only change in procedure was that food was never presented.

RESULTS

As in Experiments 1 and 2, there was no indication that key color affected rate. The major findings are shown in Figures 2 (8-sec stimuli) and 3 (20-sec stimuli). Each curve shows one bird's mean rate of responding to one of the stimuli. The Y-axis represents the mean rate of responding to the stimulus in responses per minute and the X-axis represents sessions. By the end of training, all birds responded during stimuli that were followed by food from 100% to 4% of the time at rates between approximately 20 and 150 responses per minute. At the same time, responding was not maintained to the stimulus that was never followed by food. Three birds in the 8-sec stimulus condition did not make a single response to the 0/27 stimulus during the last eight sessions. Three of the four 20-sec stimulus birds failed to respond to the 0/27 stimulus in some of the last 10 sessions. The most responses to this stimulus by any subject in one of the last 10 sessions was 53.

For each bird, the rank order correlation between probability of food following a stimulus and total responses to that stimulus during Session 10 to the end of training was 1.0 for the 9/27, 3/27, 1/27, and 0/27 stimuli. The continuous reinforcement (27/27) stimulus produced the highest rate for two birds (638 and 628), about the same rate as the 9/27 stimulus for three (2, 14, and 647), and a lower rate for the others (1, 5, and 612) during a large part of the training. Anticipatory feeder approach may have interfered with responding to the 27/27 stimulus.

Several birds (*e.g.*, S-5, S-14, S-612, and S-647) responded to the 0/27 stimulus at a rate above 20 responses per minute in one of the first two sessions. Responding stopped or markedly declined to this stimulus and in some cases to the 1/27 and 3/27 stimuli as well. Presumably, the high rate of responding to these stimuli early in training was a result of stimulus generalization. All birds responded at a low level during the ITI. Most ITI responses were "run-over" responses occurring immediately after the ITI stimulus was presented. As measured by days to regular autopecking, acquisition was delayed if only 1/27 or 3/27 of the stimulus presentations were followed by food. However, when acquisition rate was measured by number of antecedent presentations of food following a particular stimulus, acquisition was at least as rapid under the 1/27 conditions as any other. The acquisition data did not differ reliably for 8- and 20-sec stimuli, although rate of acquisition and final level of performance tended to be slightly lower with 20-sec stimuli. Apparently as a between-subjects variable, stimulus duration does not have a marked effect under these conditions.

Three of the four birds extinguished showed clear decrements on the first day of extinction, and pecking nearly stopped for all birds by the third day. For all birds, the relative rates of responding to the different stimuli remained about the same throughout extinction.

In addition to the eight pigeons studied in this experiment, six other birds received training with a single 8-sec stimulus followed by food on an irregular 1/5, 1/10, or 1/20 trials under conditions otherwise like those reported here for the multiple-stimulus procedure. Two birds received each proportion of

Fig. 2. Results for subjects in Experiment 3 with 8-sec stimuli. Each graph presents the results for a single bird. Each curve represents rate of responding to a stimulus followed by food 0, 1, 3, 9, or 27 of the 27 times it was presented in each session.

food trials and all six birds responded at rates comparable to those shown in Figure 2 and 3 for stimuli followed by food on about the same proportion of trials.

EXPERIMENT 4

Experiment 4 determined whether proportion of trials followed by food or stimulus duration has the greater effect on rate of autopecking when they covary in such a way that there is no difference in food presentations per unit of time the stimulus is present.

METHOD

Subjects and Apparatus

The apparatus was as in Experiment 1, and the subjects were eight naive pigeons.

Procedure

A within-subject design was employed in which two different keylights were presented to each subject. Stimulus 4 was presented for 4-sec and followed by food on an unpredictable one in eight presentations. Stimulus 32 was of 32-sec duration and was always fol-

Fig. 3. Results for the four birds in Experiment 3 with 20-sec stimuli. Data are plotted as in Figure 2. The last three sessions (31 to 33) were extinction sessions in which no food was presented.

lowed by food. The sequence of presentations of the stimuli was unpredictable and the ITI was always 32 sec.

The four Group A birds received 24 presentations each of Stimuli 4 and 32 in each of 16 daily sessions. The four Group B subjects received 72 presentations of Stimulus 4 and nine presentations of Stimulus 32 in each of 20 daily sessions. Thus, the number of Stimulus 4 and Stimulus 32 presentations was equated for Group A. For Group B, the number of food presentations following each stimulus and total time each stimulus was present were both equated.

RESULTS

The results are summarized in Figure 4, which shows separate plots for Groups A and B. Each curve represents mean responses per minute during Stimulus 4 and Stimulus 32.

It is obvious from Figure 4 that both groups responded much more rapidly during Stimulus 4 than Stimulus 32. The range of rates for individual birds on the last three days combined was 76.2 to 176.7 and 14.2 to 49.3 for Stimulus 4 and 32 respectively for Group A, and 126.0 and 225.1 and 20.8 to 137.3 for Group B. Every bird responded more rapidly during Stimulus 4 than during Stimulus 32 in each of the last three sessions. The consistency of this rate difference for individual subjects indicates that rate of responding was reliably greater to Stimulus 4.

For both groups, the duration of the stimuli and the proportion of stimulus presentations followed by food both differed by a factor of eight and were negatively correlated. Thus, the design permits a comparison of the relative strength of these two variables on rate of responding. Under the particular conditions employed, the effect of stimulus dura-

Fig. 4. Mean responses per minute for the four subjects in each group of Experiment 4. Each curve represents mean pecks per minute to one of the stimuli during each session for the group indicated.

tion is greater than the effect of the proportion of trials followed by food.

EXPERIMENT 5

The absence of autopecking when the stimulus remains on the response key at all times, *i.e.*, 0 sec ITI (*e.g.*, Brown and Jenkins, 1968) indicates that rate of pecking must be affected by ITI duration. However, there is only one report of a study specifically designed to determine how autopecking is affected by the ITI (Terrace, Gibbon, Farrell, and Baldock, 1975).

Experiment 5 determined the effect of length of the ITI on rate of autopecking.

METHOD

Subjects and Apparatus

Ten naive pigeons served. Two standard three-key Grason-Stadler pigeon test chambers with the side keys covered by tape were used. Pairs of birds were studied simultaneously.

Procedure

General conditions were as in Experiments 1 to 4, except that there was only one session of feeder habituation and on the first training session the first five food presentations lasted 10 sec and the second five lasted 8 sec.

After feeder habituation, each subject received five phases of training, each consisting of 10 sessions. Only ITI duration differed from phase to phase. The different ITIs employed were 0, 3, 5, 20, 120, and 720 sec. Each pair of birds was studied under all five ITIs, but the order was different for each pair. Throughout the experiment, the duration of the stimulus, illumination of a red light behind the response key, was 20 sec. A 4-sec grain presentation followed termination of the stimulus. During the ITI, the response key was dark. Each subject received 25 trials per session in each of 50 sessions.

RESULTS

Figures 5A to 5E present individual subject's response rates to the stimulus during each session. Each of these figures presents rate of responding during the stimulus for the pairs of birds for which the sequence of ITIs was the same. The ITIs are plotted in the same sequence (from left to right) as they were presented to the subjects in order to emphasize the effects of antecedent treatments.

Ten days under a given ITI apparently is not long enough for rate to reach steady state. Antecedent treatments affected rate of pecking during succeeding treatments. Therefore, it would not be appropriate to average data obtained for all birds on a particular ITI condition. However, Phase 1 results are not confounded by differences in past experimental treatment. No bird with short ITIs (0 or 3.5 sec) during Phase 1 responded to the stimulus during this phase, but all birds with ITIs of 120 or 720 sec during Phase 1 re-

Fig. 5. Results of Experiment 5. Each of panels A through E shows responses per minute during the stimulus for two birds with identical treatments. The sequence of intertrial interval (ITI) conditions is different for each pair of birds and is the same as shown on the X-axis (from left to right).

sponded at rates above 60 responses per minute on at least two of the 10 days. With a Phase 1 ITI of 20 sec, one bird (C-17) pecked the stimulus only once and the other (C-16) made only 11 responses.

On the last five days of a phase, all birds responded more when the ITI was 120 and 720 sec than when it was shorter. Thus, both within- and between-subject comparisons indicate that with ITIs of 120 or 720 sec, rate of pecking is considerably higher than with ITIs of 20 sec or less. Our measures of rate of autopecking are congruent with the extensive work of Terrace *et al.* (1975) in which trials to first peck and terminal rate of responding were found to be a positive function of ITI length.

Rates during a given condition seemed to be affected by past treatments as well as the prevailing ITI. The most obvious sequence effect was that birds initially trained with short ITIs did not respond to the lighted key on the initial series, but that birds initially trained on long ITIs continued to respond when shifted to short ITIs. That there was no marked immediate decrement in rate upon a shift from a long to a short ITI is hardly surprising, but in some cases (most notably C-16 and C-17) little decrement occurred over a total of 20 days.

EXPERIMENT 6

Autopecking rate is a positive function of ITI duration (Experiment 5) and a negative function of stimulus duration (Experiment 2), but only limited data are available (Groves and Brownstein, 1973) on how these two variables interact. Experiment 6 was designed to obtain data on the effects of covarying stimulus and ITI durations.

METHOD

Subjects

Twenty-four naive birds were used. There were originally four in each of the four groups; subsequently, four more were added to Groups 4-4 and 20-20.

Procedure

The four groups formed a 2×2 design. One variable was stimulus duration (4 or 20 sec), the other was the ratio of duration of the stimulus to duration of the ITI (1:1 or

1:5). Thus, the 4-sec stimulus groups had ITIs of 4 or 20 sec and the 20-sec stimulus groups had ITIs of 20 or 100 sec. The groups were designated 4-4, 4-20, 20-20, and 20-100 with the first number representing the duration of the stimulus and the second representing ITI duration in seconds. For all groups, the 4-sec period of grain access was initiated when transillumination of the key was terminated. All subjects received 40 trials in each of 20 sessions.

RESULTS

The mean rate of responding during the stimulus for each group in each session is shown in Figure 6; as can be seen, both longer ITIs and shorter stimuli were conducive to a higher rate of responding. Also, the rate of responding to the stimulus during the last five sessions combined for Group 4-4 was significantly greater than for Group 20-20 ($U = 7$, $p < 0.01$). Thus, when stimulus duration was the same as ITI duration, rate of responding was greater with briefer stimuli. Only one bird in Group 20-20 responded regularly at a rate above one response per minute. Most 20-20 birds never pecked the stimulus more than three times a session and did not peck at all on most days. Thus, most of the 20-20 birds behaved like the two subjects in Experiment 5, whose first treatment also involved stimuli and ITIs of 20 sec each. The results of Experiment 6 are entirely congruent

with those obtained by Groves and Brownstein (1973).

EXPERIMENT 7

Experiment 7 determined whether rate of autopecking would be affected by duration of food presentations.

METHOD

Subjects and Apparatus

Twelve pigeons served. Four of the boxes used in previous experiments were modified by adding a photocell on the front lip of the feeder (Ferne, 1971). This allowed specification of duration of feeding in terms of time from entry of the pigeon's head into the feeder opening. Except for retraction of the feeder and the attendant changes in lighting, which were timed separately for each subject, the same equipment controlled events in all four boxes.

Procedure

Feeder habituation was essentially as in Experiments 1 to 5 except that in the latter part of habituation, duration of food presentations were as in the training that came next.

Each bird received three phases of training differing only in the duration of food presentation (either 1, 3, or 9 sec) measured from insertion of the bird's head in the feeder opening or 4 sec after presentation of the food tray, whichever came first. (Birds almost always started eating within 4 sec of food presentation.) Two birds received each of the six possible sequences of food durations, *e.g.*, two birds had 1-sec food in Phase 1, 3 sec in Phase 2, and 9 sec in Phase 3. There were 36 daily sessions in Phase 1, and 18 each in Phases 2 and 3. Successive phases were separated by seven days, during which body weight was held constant by daily feedings. This break between phases was intended to facilitate rapid behavior change and to give the experimenter a vacation.

Within a session, each subject received 18 presentations of each of three different 10-sec stimuli on the response key. Food presentations followed stimuli 9/18, 1/18, and 0/18, respectively, on 9, 1, and 0 of the 18 presentations in each session. Two stimuli with different proportions of food trials were included in an attempt to assure that rate of respond-

Fig. 6. Results of Experiment 6. Mean rate of pecking in responses per minute during the stimulus in each of 20 sessions for the four groups in Experiment 6.

Fig. 7. Summary of results of Experiment 7. Mean rate of responses per minute to each combination of food duration (1, 3, or 9 sec) and probability of reinforcement (1/2 or 1/9) in each session. Each point is based on a mean for four birds. The same set of birds receive both stimuli followed by the same duration of food in a given session.

ing to at least one stimulus would provide a sensitive measure. Stimulus 0/18 was included to indicate if the stimuli were well discriminated.

Each session contained 18 cycles in which each stimulus was presented once, with the order of stimulus presentations varying from cycle to cycle. Otherwise, order of trials was unsystematic. The ITI was 30 sec.

RESULTS

Rates to stimulus 0/18 were reliably lower than to either of the other stimuli, and in most cases were below one response per minute at the end of each phase. Apparently, the stimuli were discriminated.

Figure 7 shows the mean rate to the 9/18 and 1/18 stimuli with each food duration for each block of three sessions. Within each phase, the pairs of curves for the same duration of food are based on means for the same four pigeons. For all food durations, rate of pecking was much higher to stimulus 9/18 than to stimulus 1/18. Every bird had a higher mean rate to stimulus 9/18 than stimulus 1/18 on the last six days of each phase. As in Experiment 3, probability of food had a reliable effect.

The effect of food duration was much less than the effect of probability of food and was moderately systematic only for stimulus 9/18. The curve for stimulus 9/18 with 9-sec food in Phase 3 is lower than one might expect

from Phases 1 and 2. This is due primarily to one bird that started off-key pecking during Phase 3. Observations of this bird indicated that if its responses had been on the key, the 9-sec, 9/18 curve in Phase 3 would have been above the 3- and 1-sec curves.

A comparison of the rate to Stimulus 9/18 when followed by 1-sec food (upper dotted curve of Figure 7) with the rate to Stimulus 1/18 when followed by 9-sec food (lower heavy broken curve of Figure 7) is of particular interest. These two conditions represent the same ratio of time food is available to total stimulus presentation time (9/180 or 0.05). The rate to the 9/18 stimulus during the 1-sec food phase was higher than the rate to the 1/18 stimulus during the 9-sec food phase for every subject. Thus, it is clear that, at least for these conditions, probability of food had a greater effect than duration of food presentation.

EXPERIMENT 8

Experiment 8 determined if the effect of duration of food presentation would have a greater effect than in Experiment 7 if different food durations were associated with different stimuli within the same session. A secondary objective was to see if food duration effects would be greater if each food duration was paired with a different feeder light.

Subjects and Apparatus

Eight pigeons, four naive and four that had served as pilot subjects for Experiment 7 five months earlier, served. Two of the boxes employed in Experiment 7 were modified by adding red and green feeder lights.

Procedure

In 40 sessions, each of two stimuli (vertical or horizontal black and white stripes) was presented 90 times and followed by food 10 times. Food presentations were for 1 sec following one stimulus and for 9 sec following the other. The sequence of trials was unpredictable and all ITIs were 30 sec. Half the birds had different (red or green) feeder lights for each food duration (Condition D), the others had a white feeder light during both durations (Condition ND). Stimuli (horizontal and vertical stripes) and color of feeder lights were counterbalanced across subjects.

After 28 sessions, the relationship between stimulus and food duration was reversed, *e.g.*, if the horizontal stimulus had been followed by 9-sec food presentations in the first 28 sessions (Phase 1) it was followed by 1-sec food presentations during the last 12 (Phase 2). Conditions D and ND were also reversed after Session 28.

RESULTS

One bird died near the end of the experiment. However, since its illness was not apparent in any way until after the tenth session following the change in conditions, and all subjects appeared to have reached steady state before the seventh session after the change, data from Sessions 7 to 9 of Phase 2 were used as a measure of steady-state performance. Sessions 26 to 28 were used as the measure of steady state for Phase 1. No systematic trends were apparent in Phase 1 after about Session 20.

In order to obtain a single measure of relative rate of autopecking to stimuli preceding 1- and 9-sec food presentations for each bird, mean rates on the three days measuring steady state were first obtained. Then, rate to the 9-sec food condition was divided by the sum of the rates to 9- and 1-sec conditions. These indices of relative rates at steady state in Phases 1 and 2 were averaged, giving an overall index of relative rate for each bird. Every index was above 0.5, the expected value should food duration have no effect. The mean of the indices was 0.56 (range 0.52 to 0.61). Thus, although the effect of food duration was reliable ($p < 0.01$ from expansion of the binominal), it was weak. A nine-fold increase in food duration increased mean rate of responding by less than 30%. At no time were there systematic differences in results for D and ND conditions.

GENERAL DISCUSSION

Several specific conclusions can be drawn from the present experiments. One is that, at least under the conditions of our experiments, specific color, brightness, or pattern of the stimulus had little effect on rate of autopecking at steady state so long as the stimulus was discriminable, at least moderately salient, and localized entirely on the key. Variables that our experiments have shown to affect rate of

autopecking at steady state are: (a) per cent of the stimulus presentations followed by food, (b) stimulus duration, (c) ITI duration, and (d) food duration. Since all food presentations were at termination of the stimulus in the present experiments, one cannot be certain if analogous results would be obtained with procedures involving response-independent food presentations in the presence of the stimulus rather than at its termination (*e.g.*, Gamzu and Williams, 1971, 1973). However, cross-experiment comparisons suggest that there is such comparability.

Considerable autopecking was obtained in both within- and between-subject designs with no more than 5% of the stimulus presentations followed by food. This result is in contrast with the results of most response-independent procedures. In most other instances of Type S conditioning, *e.g.*, Pavlov's experiments, little conditioning was obtained unless a large portion of conditioned stimulus (CS) presentations were followed by the unconditioned stimulus (US).

The phenomenon of autopecking does not seem to fit at all well into one or the other classes of learned behaviors described variously as classical conditioning or instrumental learning, and as operant or respondent. Nevertheless, the procedure employed in autopeck experiments is clearly response-independent or Type S conditioning (Skinner, 1938). Thus, if the terms CS and US are used to designate the first and second stimuli presented in a response-independent, paired-stimulus procedure, the stimulus on the key is the CS and food is the US in our experiments. The way in which key pecking is affected by paired-stimulus procedures differs from typical classically conditioned, *i.e.*, respondent, behavior in at least the following respects: (1) the response measured is identical to one of the operant responses most extensively investigated and thus is a "voluntary" response on at least some occasions, (2) the location of the CS is critical for acquisition of the autopeck response. (In most paired-stimulus procedures, any neutral stimulus may serve as the CS and come to evoke a conditioned response); (3) in autopecking, unlike most classically conditioned responses, the per cent of CS presentations followed by the US need not be high for rapid acquisition and persistence of the conditioned response.

Kimble (1961, p. 103) emphasized that while most variables affect classically conditioned (respondent) and instrumentally conditioned (operant) responses in about the same way, probability of reinforcement (*i.e.*, US presentation for classical conditioning and reward for instrumental conditioning) has different effects on the two forms of conditioning, a higher probability being required to classical conditioning.

Response-dependent and response-independent procedures can be clearly distinguished. However, there does not seem to be any comparable division of learning processes. Because it does not fit neatly into traditional categories, autopecking illustrates that the identification of functional processes with specific experimental procedures simply is not justifiable in the light of experimental findings.

The present experiments add to the considerable evidence that the key-pecking response in pigeons can be established and maintained by response-independent procedures. The factors that lead to autopecking and those that lead to operant pecking are present during complex response-dependent procedures. Therefore, in such experiments, key-pecking rate is not an appropriate measure of response-dependent (operant?) effects. On the other hand, key pecking in pigeons is exceptionally well suited for study of the joint operation of those effects that are separately studied by response-independent, Type S procedures and simple response-dependent, type R procedures in which the reinforcer is the only stimulus presented at any time while the experiment is in progress.

REFERENCES

- Brown, P. L. and Jenkins, H. M. Auto-shaping of the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Fernie, R. W. A device for measuring food-magazine behavior in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 409-410.
- Gamzu, E. and Williams, D. R. Classical conditioning of a complex skeletal response. *Science*, 1971, 171, 923-925.
- Gamzu, E. R. and Williams, D. R. Associative factors underlying the pigeon's key pecking in autoshaping procedures. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 225-232.
- Gonzales, F. A. Effects of partial reinforcement (25%) in an autoshaping procedure. *Bulletin of the Psychonomic Society*, 1973, 2, 299-301.
- Groves, L. C. and Brownstein, A. J. Effects of trial and cycle duration on automaintenance. Paper presented at the annual meeting of the Southeastern Psychological Association, New Orleans, April, 1973.
- Hearst, E. and Jenkins, H. M. *Sign-tracking: the stimulus-reinforcer relation and directed action*. Austin, Texas: Psychonomic Society, 1974.
- Jenkins, H. M. Sequential organization in schedules of reinforcement. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules*. New York: Appleton-Century-Crofts, 1970. Pp. 63-109.
- Kimble, G. A. *Hilgard and Marquis' conditioning and learning*. New York: Appleton-Century-Crofts, 1961.
- Myers, J. L. The effect of delay of reinforcement upon an operant discrimination in the pigeon. *Journal of Experimental Psychology*, 1958, 55, 363-368.
- Redford, M. E. and Perkins, C. C. The role of autopecking in behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1974, 21, 145-150.
- Ricci, J. A. Key pecking under response-independent food presentation after long simple and compound stimuli. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 509-516.
- Schwartz, B. and Williams, D. R. Two different kinds of key peck in the pigeon: some properties of responses maintained by negative and positive response-reinforcer contingencies. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 201-216.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century-Crofts, 1938.
- Terrace, H. S., Gibbon, J., Farrell, L., and Baldock, M. D. Temporal factors influencing the acquisition and maintenance of an auto-shaped keypeck. *Animal Learning and Behavior*, 1975, 3, 53-62.
- Thomas, D. R. and Caronite, S. C. Stimulus generalization of a positive conditioned reinforcer: II. Effects of discrimination training. *Journal of Experimental Psychology*, 1964, 68, 402-406.
- Wasserman, E. A. The effect of redundant contextual stimuli on autoshaping the pigeon's keypeck. *Animal Learning and Behavior*, 1973, 1, 198-206.
- Williams, D. R. and Williams, H. Auto-maintenance in the pigeon: sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 511-520.

Received 30 July 1974.

(Final Acceptance 18 February 1975.)