EFFECTS OF VARYING THE PERCENTAGE OF KEY ILLUMINATIONS PAIRED WITH FOOD IN A POSITIVE AUTOMAINTEANCE PROCEDURE¹

FERNANDO A. GONZALEZ

HARVARD MEDICAL SCHOOL AND
NEW ENGLAND REGIONAL PRIMATE RESEARCH CENTER

Three pigeons were exposed to a positive automaintenance procedure in which each trial began with a brief tone followed by the transillumination of a small central area of the response key for 10 sec. Key illumination was followed by food on 100%, 50%, 25%, 12.5%, and 0% of the trials. The effects depended on the dependent variable observed. The mean rate of responding during key illumination rapidly increased and then decreased slightly as the percentage of key illuminations paired with food increased. The number of key illuminations during which at least one response occurred increased as a negatively accelerating function of the percentage of key illuminations paired with food, and the mean latency to the first response during the key illuminations decreased as a negatively decelerating function of the percentage condition. The mean rate of sustained responding during key illumination was not systematically affected by changes in the percentage conditions.

In the positive automaintenance procedure, a pigeon's response key is illuminated for several seconds before each response-independent presentation of grain. Responses have no scheduled consequence, and food is never presented in the absence of key illumination. Experimentally naive pigeons soon begin to peck the key when it is illuminated (autoshaping) and eventually reach a stable maintained level of responding (automaintenance). Many of the autoshaping and automaintenance experiments studied how the principles of Pavlovian conditioning and of operant conditioning can account for these phenomena (*e.g.*, Gamzu and Schwartz, 1973; Gamzu and Williams, 1971, 1973; Hursh, Naravick, and Fantino, 1974; Schwartz and Williams, 1972a; Wessells, 1974; Williams and Williams, 1969). Several experiments explored variables that affect autoshaping in pigeons (*e.g.*, Brown and Jenkins, 1968; Engberg, Hansen, Welker, and

Thomas, 1971; Gonzalez, 1973; Wasserman, Markman, and Hearst, 1971). However, parametric studies are lacking.

One of the variables that can affect auto-shaping is the percentage of key illuminations followed by food presentation (*i.e.*, "partial reinforcement"). Gamzu and Williams (1971), Williams and Williams (1969), and Winokur and Frank (1973) have shown that key pecking can be established and maintained by automaintenance procedures in which key illuminations are only occasionally paired with food. Schwartz and Williams (1972b) found that key-peck duration and response rate first increased and then decreased as the percentage of key illuminations paired with food was decreased. Gonzalez (1973) showed that when only 25% of the key illuminations were followed by food, pigeons reached their terminal performances more slowly than when every key illumination was followed by food. In addition, mean response latencies during key illuminations were longer.

The present experiment sought to determine the functional relationship between the percentage of key illuminations followed by food and the mean response rate during key illumination, the number of key illuminations during which responding occurred, the mean latency to the first response during key illumination, and the mean rate of sustained responding (running rate) during key illumination. Most automaintenance studies

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have used either the first or second of these dependent variables. The study by Gonzalez (1973) suggested that mean response latency could also be a sensitive dependent variable in automaintenance experiments. It was of interest to examine how all of the above measures covaried as percentage of food presentations was systematically manipulated.

METHOD

Subjects

Three male White Carneaux pigeons were maintained at 80% of their free-feeding weights. Their experimental histories consisted of several hours of exposure to a procedure in which 9-sec key illuminations were always followed by 4-sec access to grain (Gonzalez, 1973). Autoshaping had occurred rapidly.

Apparatus

Three identical pigeon chambers each measured 25 by 23 by 40 cm. The 1.5-cm diameter response key (Lehigh Valley Electronics) was located 19 cm above the floor. A circular area of the key 0.6 cm in diameter could be transilluminated with white light. This stimulus was used to eliminate the offkey responses that at least one subject (Pigeon 408) made during initial sessions when the entire key was transilluminated. No pecks outside the key were observed thereafter. The food tray was located below the response key. During food presentation, the tray was illuminated with white light. Two 7.5-W green houselights were located above the translucent Plexiglas ceiling. Two speakers were mounted on the side of each chamber. One speaker provided continuous white noise, and the other provided a loud high-pitched tone. Scheduling and recording equipment were located in an adjacent room.

Procedure

The three pigeons were studied simultaneously and were always exposed to identical procedures. With few exceptions, the sessions took place seven days a week at approximately the same time each day. Each session consisted of 100 trials separated by 45-sec intertrial intervals. Each trial began with the presentation of the tone for a minimum of 5 sec followed by transillumination of the central area of the response key for 10 sec. Key pecks occur-

ring during the tone prolonged its presentation and postponed key illumination until 5 sec had elapsed without a key peck. This contingency was yoked across the three chambers so that the temporal distribution of the trials was identical for the three subjects. Responses occurring during key illumination had no scheduled consequence. The houselight was turned off during food presentation and during the blackouts.

The percentage of key illuminations followed by food presentation (food trials) was varied by substituting blackouts for food. Two different sequences of occurrence of the food trials for each percentage condition were developed by means of a random-number table. They alternated daily. The percentages of food trials were 100, 50, 25, 12.5, and 0 (extinction). These percentages occurred in the above order and remained in effect for 60, 20, 45, 25, and 3 sessions respectively. The percentage condition was changed when no trends were apparent in any of the behavioral measures over the last 10 sessions. Following extinction, the pigeons were again exposed to the 25% (15 sessions) and to the 100% (six sessions) conditions.

RESULTS

Responding occurred during key illumination at all percentages of food trials except 0%. The subjects seldom responded during the intertrial intervals, and only Pigeon 410 responded during the tone. This subject averaged 1.2 responses per tone presentation under the 100% and 50% conditions, and 0.2 responses per tone under the 25% condition. However, responding occurred in less than half of the tone presentations. Since responding during the tone prolonged its presentation, the mean duration of the tone was 8.3 sec at the 100% and 50% conditions and 5.5 sec at the 25% condition.

Performance during key illumination was characterized by a period of no responding (latency) followed by responding at a high stable rate until keylight offset. The top row of Figure 1 shows the mean rate of responding during key illumination (number of responses during key illumination/time of key illumination) as a function of the percentage of food trials (last 10 sessions under each percentage). Reading from right to left,

Fig. 1. Effects of varying the percentage of key illuminations paired with food (food trials) on four dependent variables. The graphs in each column correspond to the individual subjects. The rows are the four behavioral measures. The points joined together with heavy lines are the means of the behavioral measures for the last 10 sessions under each percentage condition. The vertical lines join one standard deviation above and below the means. The open circles are the means of redeterminations at 25% (last five days) and 100% (last three days).

mean response rate first increased slightly and then decreased as the percentage of food trials was reduced. Mean response rate was highest at 50% food trials. Although it is not shown in the graphs, responding did not

occur during the key illuminations after only 1.5 sessions of the 0% condition. Redetermination of mean response rates at 25% and 100% food trials (open circles) approximated the initial determinations. For Pigeons

406 and 410, variability increased as the percentage of food trials was reduced.

The number of key illuminations during which at least one response occurred increased as a negatively accelerating function of the percentage of food trials (Figure 1, second row). At the 100% and 50% conditions, responding occurred during practically all key illuminations. In the 25% condition, Pigeons 406 and 408 responded during approximately 90% of the key illuminations, but Pigeon 410 continued to peck during almost all of the key illuminations. The mean number of key illuminations during which responding occurred, however, sharply decreased for the three subjects when only 12.5% of the key illuminations were followed by food presentation. The mean number of key illuminations during which responding occurred was approximately recovered upon re-exposure to the 25% and 100% conditions. Variability was least at 100% and increased as the percentage of food trials was reduced.

The mean latency of the first response (only signals during which responses occurred contributed to this measure) was a negatively decelerating function of the percentage of food trials (Figure 1, third row). The mean latencies of Pigeon 408 were longer at all percentage conditions than those of the other two subjects. At 50%, the mean latencies of Pigeons 406 and 410 were approximately twice as long as at the 100% condition. No change in mean latency was observed in Pigeon 408 when the percentage of food trials was changed from 100% to 50%. Further reductions in the percentage of food trials resulted in progressively longer mean latencies in all three subjects. Variability tended to increase

with the reductions in the percentage conditions. Redetermined latencies under the 25% and 100% conditions approximated satisfactorily those obtained initially.

The bottom row of Figure 1 shows the mean rate of sustained responding. Rate of sustained responding was defined as the ratio of the number of responses emitted during a key illumination to the difference between the duration of key illumination (*i.e.*, 10 sec) and the latency to the first response. Only key illuminations in which responding occurred contributed to this measure. Generally, the rates were four to eight responses per second. These high rates were correlated with a characteristic key-pecking topography: the subjects held their opened beaks against the illuminated area of the key and shook their heads. The functions were not similar across the three subjects. For Pigeons 406 and 410, the mean rate of sustained responding increased slightly when the percentage of food trials was changed from 100% to 50%, but decreased when the percentage was further reduced. The largest changes were obtained with Pigeon 408. For this subject, the rate of sustained responding appeared to be an inverse linear function of the percentage of food trials. Variability was constant for each subject over the range of percentage conditions.

Figure 2 illustrates the changes in the distribution of latencies as the percentage of food trials was varied. Each curve in this figure is the relative frequency distribution of the latencies from n successive key illuminations during which responding occurred, from one or more complete sessions (one session at 100%, two sessions at 25%, and three sessions at 12.5%). Individual latencies were not re-

Fig. 2. Effects of varying the percentage of key illuminations paired with food presentation on the relative frequency distribution of the latency to the first response during the key illuminations. Each curve corresponds to a percentage condition as indicated in the insert, and n is the sample size.

corded until the 12.5% condition was initiated; therefore, the 25% and 100% latency distributions shown in the figure were obtained during the redeterminations. At 100% food trials, most latencies were shorter than 1 sec. Short latencies were also most frequent at 25% food trials, but at this percentage condition a substantial number of longer latencies occurred. At 12.5% food trials, latencies in each class interval occurred with similar frequency.

DISCUSSION

The procedure engendered stable key-pecking performances that were similarly affected by changes in the percentage of trials in which food was presented. Two of the four behavioral measures recorded, the mean latency to the first response during key illumination and the number of key illuminations during which at least one response occurred, were, respectively, monotonically decreasing and monotonically increasing functions of the percentage of food trials. Mean latency approached its asymptotic level more gradually than did the number of key illuminations with responses, and was the more sensitive measure at the higher percentages of food trials. The changes in the mean latencies reflected increases in latency variability, rather than shifts in the mode of the latency distributions. The mean rate of sustained responding during key illumination was an inverted U-shaped function of the percentage of food trials for two subjects, and a decreasing linear function for the third. This measure was the least sensitive to changes in the percentage of food trials. Finally, a composite of the above three measures, the mean rate of responding during key illumination, first increased and then decreased slightly as the percentage of food trials increased. Although mean rate of responding during key illumination appeared to be an adequate summary measure of the effects of varying the percentage of food trials, the other three measures were necessary to describe fully the changes in performance. Since different values of these three measures can combine to produce the same mean response rate, the three measures are needed to assess adequately the effectiveness of independent variables. These measures are easily recorded and should

be considered in other experiments involving the automaintenance procedure.

The mean response rates were generally higher than those reported in other studies (Gamzu and Williams, 1971, 1973; Gonzalez, 1973; Schwartz and Williams 1972*b*; Winkur and Frank, 1973). Exclusive features of this study, that is, the particular response-key stimulus used, the fixed intertrial intervals, and the tone preceding the key illuminations, may account for the differences. By reducing the size of the illuminated area of the key, pecking responses outside the key were eliminated. If the subjects redirected those responses towards the key, increased response rates would be expected. The small stimulus may also have contributed to the development of the characteristic response topographies. The tone was added in an attempt to increase the likelihood that the subjects would be oriented towards the key at the moment of illumination and thereby reduce the variability of response latencies. No attempt was made to assess the effect of the tone; however, if the tone resulted in shorter latencies, then increased mean response rates would be expected.

The somewhat different durations of the tone presentations across the various percentages of food trials may have been a confounding factor. However, except for the generally higher response rates, the present results are consistent with previous findings of the effects of "partial reinforcement" in automaintenance procedures. Gonzalez (1973) showed that the response latencies of pigeons exposed to a positive automaintenance procedure in which only 25% of the key illuminations were followed by food were substantially longer than the latencies of pigeons for which every key illumination was paired with food. The number of key illuminations with responses were only slightly lower for the 25% group, and the rates of sustained responding did not differ between groups. Schwartz and Williams (1972*b*) varied the percentage of key illuminations followed by food in a positive automaintenance procedure. They reported that the rates of key pecking were higher at 50% and 20% food trials than at 100%, but were lower at 5% than at 100% food trials.

The positive automaintenance procedure is formally similar to the Pavlovian delay conditioning procedure. In general, Pavlovian con-

ditioning experiments in which the percentage of conditioned stimulus-unconditioned stimulus (CS-UCS) pairings was manipulated have yielded results similar in some respects to the present results. Usually, low percentages of CS-UCS pairings have been found to retard acquisition and result in lower asymptotic levels of conditioned response (*cf.*, Kimble, 1961, p. 103; Seward, 1970). Because of the considerable procedural differences, it is more difficult to compare this experiment with those studying percentage reinforcement in operant conditioning. Several of those studies, however, have yielded results similar to this experiment. Ferster and Skinner (1957, p. 67-71) studied two pigeons under a procedure in which every thirtieth response (fixed ratio 30) produced food plus a 3-min blackout. They subsequently eliminated up to 50% of the food presentations (but not the blackouts) and found that the postreinforcement pauses tended to increase with decreases in the percentage of food reinforcements, but that rates of sustained responding were not affected. Zimmerman (1960) trained water-deprived rats on a simple discrimination procedure in which the first lever-pressing response emitted during the discriminative stimulus produced water plus a 2-min timeout. After the discrimination was established, water was made available only in a small percentage of the stimuli, and longer and more variable latencies resulted. Later, Zimmerman required 10 responses (fixed ratio 10) to produce the water and the timeout. Under that procedure, percentage reinforcement again resulted in increased latencies, but had no effect on running rate. Zeiler (1972, Experiment I) found that the mean response rate of pigeons under fixed-interval (FI) schedules first increased and then decreased as the percentage of FI components terminating in reinforcement increased. Finally, the effects of changes in the percentage of key illuminations paired with food presentations on response latency were qualitatively similar to the effects of percentage reinforcement on the "reaction time" of rats (Stebbins and Lanson, 1962). In summary, the effects of varying the percentage of key illuminations paired with food in a positive automaintenance procedure appear to be similar to the effects that comparable manipulations have on behaviors maintained by other procedures.

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