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A RAPID AUTOMATIC TECHNIQUE FOR GENERATING OPERANT KEY-PRESS BEHAVIOR IN RATS[1]

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Experimentally naive rats were trained to key press on a fixed-ratio 10 schedule of food reinforcement by a completely automatic procedure within a single, 1-hr session. Control procedures demonstrated that the resulting behavior was an operant, under control of the schedule of reinforcement and the specified reinforcing stimulus (food). A simple, combination food-tray operandum, also described, was used as the basis for the training technique.

Teichner (1952) and Bremner and Trowill (1962) described combined operandum-reinforcement devices for use with food pellets, which facilitated lever-press training of rats and which did not require response shaping by an experimenter. Procedures in which responding was automatically acquired have also been used with rhesus monkeys (Sidman and Fletcher, 1968) and bobwhite quail (Gardner, 1969), based on the procedure developed by Brown and Jenkins (1968) for use with pigeons. Gardner and others (*e.g.*, Wilton and Gay, 1969) have further demonstrated that quail and pigeons can be shifted from the automatic training procedure to higher schedules of reinforcement.

The present report describes an automatic training procedure and operandum that appear to be superior to those reported earlier, for rapid development of schedule-controlled key-pressing in rats and automatic shifting from reinforcement for each response to reinforcement at a ratio of 10 responses per reinforcement. This technique would be useful when large numbers of rats must be trained or when experimenter time is limited. Brown and Jenkins (1968) considered the use of an illuminated key to be critical in the development of key-press responding in pigeons and attributed its importance to the species-specific tendency of the pigeon to peck at things at which it looks. The design of the response key used in these experiments was based on the species-specific tendency of hungry rats to sniff the area in which food was obtained and to "nose" objects.

METHOD

Subjects

In the present experiments, the weights of experimentally naive male Charles River rats (Sprague-Dawley) were decreased to approximately 80% of original weight (150 to 190 g) by 48 hr of food deprivation followed, on the next day, by 6 g per day of the food pellets used as reinforcers in the experimental procedures. Three different rats were used in each of the five experiments reported and all rats were housed in individual home cages with free access to water.

Apparatus

The rats were tested in three cubic chambers (230 mm, each dimension) with grid floors, housed in sound-attenuating, ventilated, wood boxes. Conventional scheduling and recording equipment was used. Noyes food pellets (0.045 g) were delivered into a recessed food tray (Gerbrands Recessed Tray for Model D-1 Feeder; Cat. No. G-7020), modified for use as an operandum.

As illustrated in Fig. 1, the baffle that deflects the food pellets to the bottom of the tray (A) was replaced by a Model 1348 LVE Pecking Key (B) mounted on the chamber wall by a metal bracket (C). The plastic plate, supplied with this key unit, was replaced by a 40 by 55 by 1 mm aluminum plate (D) whose

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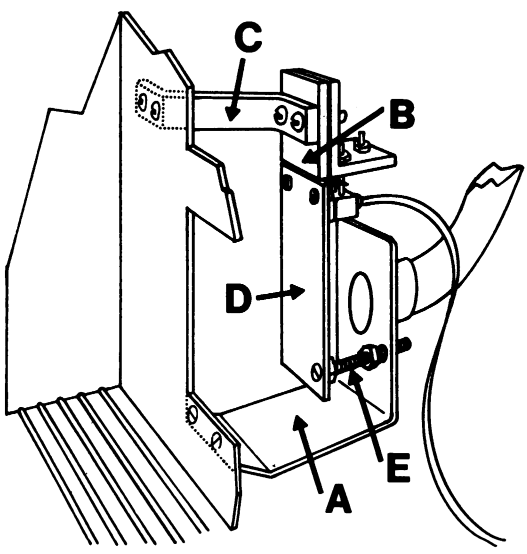

Fig. 1. Schematic of food tray modified for key-pressing by rats.

lower edge was 5 mm from the floor of the tray, to permit passage of the pellets. The key unit was mounted so that the aluminum plate (combination baffle-key) was parallel to, and at a distance of 30 mm from, the chamber wall and 15 mm from the back of the food-tray. A flat-head screw (E) was fastened to a lower corner of the key plate and passed through an opening in the rear wall of the food-tray; nuts, on either side of the tray wall, were spaced on the screw to limit the forward and backward excursion of the key plate. The rear portion of the plastic cover of the food tray was cut away sufficiently to allow clearance for the key and was hinged to permit removal for cleaning. The force required to activate the different keys ranged from 13 to 16 g (0.13-0.16N). The lower edge of the wall opening, leading to the food tray, was 24 mm above the chamber grid floor. Two small lights wired in parallel (T-1¾ lamps, #327 bulbs, with 10 ohm resistor in series), were mounted at the side of the food tray.

Procedure

Three food pellets were placed in the food-tray before an experimentally naive, food-deprived rat was placed in the chamber. As each rat found and consumed the food pellets, the isolation-box door was closed and the apparatus turned on. Magazine training was accomplished by automatically delivering four food pellets at variable intervals of time (mean 24 sec). The procedure then switched to a response-contingent reinforcement schedule of one pellet for each key press, for a total of four reinforcements. The fixed ratio (FR), at which responses produced reinforcement, increased automatically from 1 to 2, 3, 5, 7, and finally 10 (FR 10), with four reinforcements delivered at each ratio.

The lights at the side of the food tray flashed briefly with each key-press; with each reinforcement they illuminated the food tray for 5 sec and the light that illuminated the chamber was turned off. After each reinforcement a 20-sec timeout was in effect, during which the chamber remained dark and responses had no effect (Exp. I).

With a second group of rats (Exp. II), food delivery was not dependent on key-pressing behavior to determine the relationship of the behavior generated by the apparatus and procedure described above to that resulting from adventitious food reinforcement. The experimental conditions were the same as above, except that food pellets were delivered at varying intervals (mean: 24 sec) regardless of the rats' behavior. The total number of reinforcements was the same as in Exp. I and the session duration was similar.

A third group of rats (Exp. III) was tested to determine further whether the behavior observed in Exp. I was an operant under control of the FR reinforcement dependency. The apparatus and procedure were the same as in Exp. I. However, after 15 reinforcements on FR 10, the food magazine was disconnected so that responses no longer produced reinforcement.

The purpose of Exp. IV was to determine whether this procedure generated key pressing, in the absence of food, because of an intrinsic appeal or because of other factors, unrelated to food-reinforcement dependencies. The apparatus was the same as in the previous experiment, but no food was placed in the food tray initially and no food was delivered, regardless of the rats' behavior. Key presses produced only a momentary flash of the key light and if a ratio was completed, a 5-sec food-tray illumination occurred, but no food was delivered. The duration of the session was 60 min and was approximately equivalent to those of Exp. I, II, and III.

In Exp. V, the operant nature of the key-press response was further tested by measuring the development of stimulus control of the response. The apparatus and procedure in Exp. V were the same as in Exp. I except that, after 28 response-dependent reinforcements, the duration of the post-reinforcement timeout was extended. It ended either after responding ceased for 20 sec (DRO 20-sec) or after 1 min. If the timeout duration reached 1 min, it ended only when 0.5 sec elapsed since a response. Therefore, cessation of responding in timeout increased the opportunity for reinforcement by shortening the timeout duration, and sustained responding decreased the opportunity for reinforcement by prolonging timeout.

RESULTS

Experiment I. Characteristic FR Behavior

The rats characteristically sniffed about the food tray after consuming the food pellets initially placed in the food tray and delivered during magazine training. In the course of olfactory exploration, they pressed the key with their noses, thereby producing further reinforcement. A representative cumulative response record of FR responding is shown in Fig. 2-A (responses during timeout were recorded separately). Generally, the rats began to respond at high rates during either the FR 1 or FR 2 sequence and continued to respond rapidly in characteristic FR response patterns. The overall mean response rate on FR 10 was 49.9 responses per minute (median: 56.6 resp/min). During the last 15 ratios, it was 53.1 resp/min (median: 53.6 resp/min).

Experiment II. Non-Contingent Reinforcement

Adventitious reinforcement resulted in the development of superstitious response behavior. However, the pattern of responding was generally erratic and was not reliably maintained (Fig. 2-B). Two of the rats exhibited erratic initial response patterns and essentially no responding in the last portion of the session; one rat continued to respond erratically throughout the session. The mean overall response rate, exclusive of timeout response rates, was 19.9 resp/min (median: 14.4 resp/min). Over the last 15 food deliveries, it was 28.2 resp/min (median: 6 resp/min).

Experiment III. Extinction

As illustrated in Fig. 2-C, FR behavior developed as in Exp. I, but after the completion

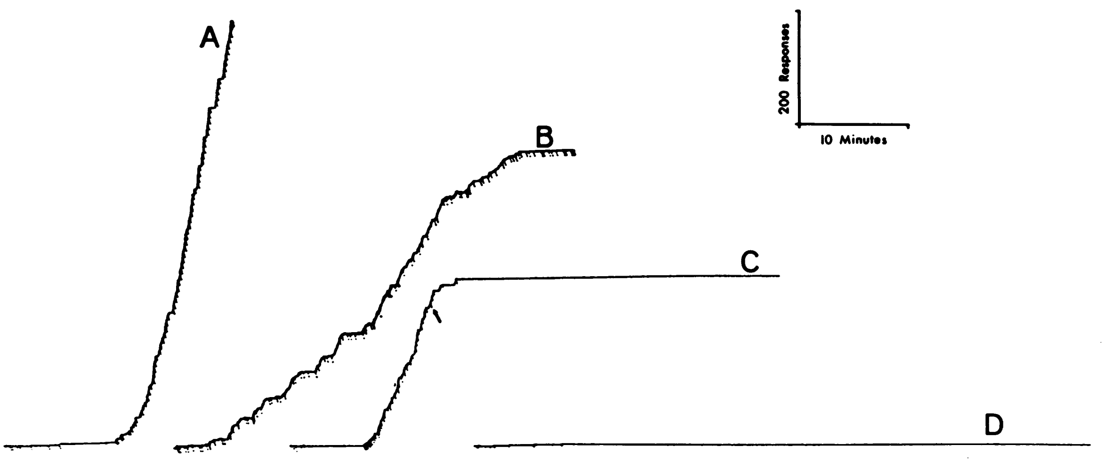

Fig. 2. Representative cumulative records of key-press responses during the schedule component (FR) in which responses were normally reinforced. The downward pen deflections indicate food deliveries except in record (D) and part of record (C). The first four reinforcements in records (A), (B), and (C) were not response dependent and constituted magazine training. A 20-sec timeout period followed the completion of each ratio and responses during this period were recorded on another recorder. Record (A) illustrates the normal development of FR 10 performance. Record (B) illustrates the effects of independent food deliveries. Record (C) is another illustration of the development of FR 10 performance followed by illustration of the effect of discontinuation of reinforcement (extinction), beginning at the arrow. Each pen deflection (in record (C)), beginning with that indicated by the arrow, shows the completion of 10 responses. Record (D) illustrates performance in the complete absence of food delivery. Each pen deflection in this record indicates when food delivery would have occurred, either during magazine training or after completion of the different response ratios.

of 5 to 10 unreinforced ratios (beginning at arrow), all rats stopped responding for the remainder of the session.

Experiment IV. No Food

As illustrated in Fig. 2-D, in the absence of food reinforcement, neither the key light nor operation of the key maintained key-pressing behavior. A few responses were emitted during early exploration of the food tray, but essentially no responses were emitted for the remainder of the session.

Experiment V. Stimulus Control

Figure 3 shows the average response rates during fixed-ratio and timeout components in each quarter of the training session. The rate of responding in FR components tended to increase slightly over the session; however, the timeout response rate, which was equal to FR rate in the first quarter of the session, decreased to less than half the FR rate by end of the session. An example of the performance ultimately achieved on this schedule of reinforcement is shown in Fig. 4. This rat was run for nine sessions after that illustrated in Fig. 3. Its overall response rate in the FR components was 109 resp/min, and 3 resp/min in timeout components. The rats generally started responding immediately after onset of the FR components and most instances of responding in timeout occurred as over-shoots of FR responding.

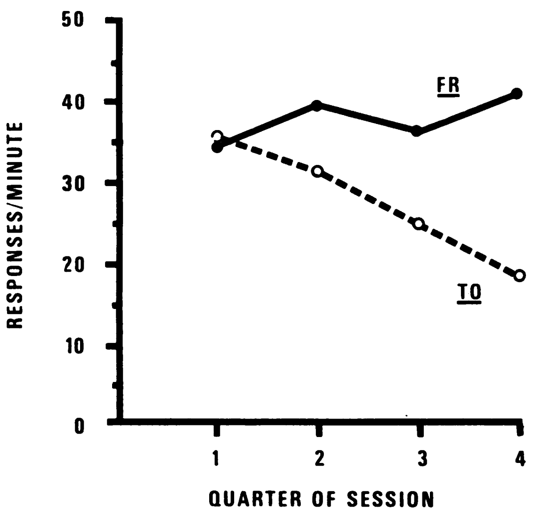

Fig. 3. Rates of responding during acquisition of discriminated behavior. Mean response rates for each quarter of the session are shown by the solid line for FR components and by the broken line for timeout (TO) components.

DISCUSSION

Using the apparatus and procedure described above (Exp. I), rats can be trained automatically to key press and can be shifted automatically to a higher schedule of reinforcement, with a minimum of experimenter effort and time, in a single experimental session (approximately 1 hr). The response rates and patterns in Exp. I were consistent with those seen with rats on FR 10 schedules of reinforcement after conventional response shaping and training procedures, and the rate of nose-press responding with this apparatus is comparable to paw-press response rates on conventional levers.

The results of Exp. V indicate that the beginning of stimulus-controlled, discriminated

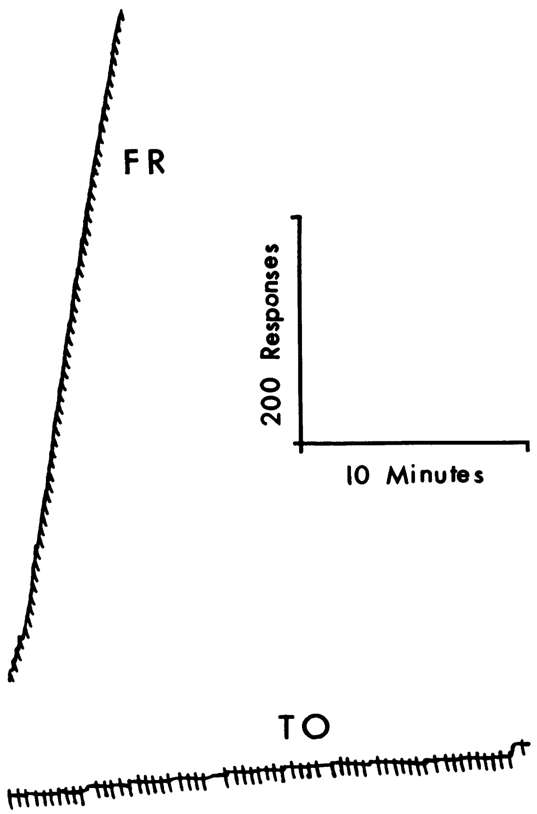

Fig. 4. Cumulative records of responses during FR components (upper record) and timeout components (TO; lower record) during the ninth session after the one shown in Fig. 3. Subsequent sessions showed no further changes from the illustrated behavior.

behavior can be measured with this technique in a single session. The results also indicate the operant nature of the key-press response: responses that delayed the opportunity for food reinforcement were not maintained; rather, they decreased.

In the absence of food delivery (Exp. IV), the unreinforced operant level of the response accounted for only a few responses at the beginning of the session. In the absence of food reinforcement, neither the intrinsic appeal key pressing may provide (Jensen, 1963) nor the light dependency (Goodrick, 1965) was sufficient to generate and maintain key-press behavior.

The extinction procedure (Exp. III) further indicated that key pressing was maintained by the food reinforcement dependency. Soon after food delivery was discontinued, the rats stopped responding. The presentation of conditioned reinforcement, in the form of the keylight and food-tray light, maintained FR behavior only through a few ratios in these rats with limited training. The rats did not stop responding because of satiety, since other work indicated that effects of satiety were not evident until the rats consumed approximately three times the number of pellets delivered in this experiment.

Although adventitious food delivery (Exp. II) did increase the unreinforced operant level of responding, response rates generally approached zero by the end of the session and none of the rats exhibited the characteristic FR behavior of the rats in Exp. I.

The automatic training procedure and combination food-tray operandum described here produced much higher rates of responding than those produced by a previously reported procedure with rats (Bremner and Trowill, 1962), in a shorter period of time, and served as the basis for the further development of performance on a higher schedule of reinforcement. Both key pressing and the development of characteristic FR 10 performance were accomplished automatically in a single session of less than 1-hr duration. Further experience with over 500 rats demonstrated that 80 to 90% could be trained as described.

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