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SCHEDULE-INDUCED DEFECATION

FREDERICK RAYFIELD, MARVIN SEGAL, AND ISRAEL GOLDIAMOND

THE UNIVERSITY OF CHICAGO

Excessive defecation, typically considered to be a concomitant of stress, was experimentally induced or eliminated under specific schedules of positive reinforcement of lever pressing by rats. The schedules were, by and large, those under which polydipsia is typically induced. In the first of three experiments, rats under fixed-interval 32-second schedules and variable interval 32-second schedules for food and water reinforcers defecated profusely, but not under fixed-interval one-second schedules or other small interval schedules. Somewhat higher rates of defecation were observed on variable interval 32-second schedules than on fixed-interval 32-second schedules. In a second experiment, fixed-ratio schedules were used, some of which resulted in responding such that reinforcement densities were similar to those on the interval schedules that induced defecation. Defecation was not systematically induced by these ratio schedules. In a third experiment, fixed-time schedules of food presentations were utilized. High rates of defecation were induced comparable to those induced by interval schedules of the same time parameter. No other behavior commonly termed "emotional" was observed in any of these experiments.

Key words: defecation, schedule-induced behavior, fixed interval, variable interval, fixed time, fixed ratio, emotionality, conditioned suppression, rats

In investigations of operant behavior, ancillary activities may be observed that are not specifically reinforced by the experimental presentation of stimuli such as food or water. Where these ancillary activities vary systematically with manipulations of the reinforcement schedule that governs an experimentally defined operant, so that they may thereby be produced or eliminated, these activities may be referred to as "adjunctive" or "schedule-induced" behavior, as distinguished from "schedule-governed" behavior, which describes the operant involved. Among such schedule-induced behavior is the polydipsia first reported by Falk (1961, 1964) in the pioneering research that brought to attention the field of schedule-induced or adjunctive behavior. In Falk's experiments, bar pressing by rats was typically reinforced by delivery of food under a VI 60-sec schedule. The robustness of the schedule-induced behavior was evident in the rats' consumption, through licking a dipper, of as much water as half their body weight during a session of 180 minutes. Such schedule-induced polydipsia has also been reported on fixed-interval reinforcement of lever pressing and during free presentations of food at regular intervals (FT schedules). Temporal schedules have been reported as inducing other similar types of behavior, such as air licking (Mendelson, Zec, & Chillag, 1971) and alcohol consumption (Falk, Samson, & Winger, 1972).

Qualitatively different activities have been induced by the same and other schedules that are not necessarily temporal or by changes in these schedules. Introduction of a high fixed-ratio requirement or a fixed-interval schedule can reliably produce biting of a bar by a restrained squirrel monkey (DeWeese, 1977; Hutchinson, Azrin, & Hunt, 1968) or attack on another pigeon by an unrestrained pigeon (Gentry, 1968). In these studies, aggression occurs when the work requirement is increased or when reinforcement density is otherwise decreased. The limiting case is extinction,

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when the work requirement tends toward an infinity limit and the reinforcement delivered tends toward a zero limit (e.g., Azrin, Hutchinson, & Hake, 1966; Reynolds, Catania, & Skinner, 1963; Rilling & Caplan, 1973). Schedules or schedule changes or other conditions identical to those producing aggression will instead produce escape, if the enclosure is sufficiently large; indeed, even when the enclosure is small, the pigeon will peck a key that turns off the discriminative stimulus associated with the schedule (Brown & Flory, 1972). Aside from induction under conditions of positive reinforcement, aggressive and escape patterns are also induced by administration of such noxious stimuli as painful electric shock (Azrin, Hutchinson, & Hake, 1963; Ulrich & Azrin, 1962) and a physical blow (Azrin, Hake, & Hutchinson, 1965), among other noxious stimuli. The same noxious stimulus that can induce aggression when the enclosure is small, or escape when it is large, can apparently also induce sexual assault on a female rat by a male (Caggiula, 1972; Caggiula & Eibergen, 1969).

In both open field studies (Hall, 1934) and the conditioned suppression or conditioned emotional response (CER) studies (Estes & Skinner, 1941) and elsewhere, defecation has been considered an indicator or concomitant of stress.

In the present series of experiments, we report the reliable induction of defecation under specifiable interval schedules, its reliable absence under other interval schedules, and its absence under fixed-ratio schedules, even when the rat's own response rate spaces the time between deliveries of food to be equal to intervals that reliably induce defecation when the schedule is an interval one.

EXPERIMENT 1
DEFECATION INDUCED BY FIXED- AND VARIABLE-INTERVAL SCHEDULES WITH FOOD AND WATER REINFORCERS

METHOD

Subjects

Twelve experimentally naive male albino Holtzman rats served. They were approximately 90 days old and weighed 283 to 311 g at the beginning of the experiment. Six rats were food-deprived to 90% of previous ad lib body weight. They had free access to water in their home cages. The other six rats were water-deprived to 90% body weight. They had free access to food in their home cages. All subjects were given access to food and water for sufficient time periods immediately after sessions to maintain them at 90% (±5%) of their original body weights. Each group of six was housed in a standard clear plastic cage in a temperature-controlled area (24-29° C) with a 12-hour-dark/12-hour-light cycle.

Apparatus

Two experimental chambers were used. Each was 21 cm by 23 cm by 26 cm high constructed of half-inch (1.27 cm) galvanized mesh. Each chamber was equipped with a 3 cm by 4 cm aluminum lever located 10 cm from the floor and operated by a downward force of .25 newtons. For the six food-deprived rats, a cup 10 cm to the left of the lever provided access to a 27-mg Noyes Formula A pellet when appropriate. For the six water-deprived rats, a cup in the same position provided access to .015 ml of water from a dipper when appropriate. The chambers were located in sound-attenuating cabinets in which a ventilating fan provided fresh air and a masking noise of 70 to 75 dB throughout the chamber. A 50-W houselight was located 25 cm above each chamber. A bolus detector was mounted below each chamber. This consisted of an aluminum funnel in the shape of an inverted pyramid with apex 25 cm below the floor of the cage. A photocell at the apex opening detected boli that fell through. At the end of each session, automatic counts from the photocell were compared with manual counts of boli in the receptacle at the bottom of the funnel and of boli adhering to the funnel walls and mesh floor. The photocell apparatus was found to record, over all sessions, an average of 80% of the hand counts. Adhesion of some boli to funnel sides and mesh floor occurred for food-deprived subjects with unlimited access to water in the home cage. The sources of inaccuracy for water-deprived subjects were small hard boli that ricocheted around the photobeam, or were too small to be detected. (An improved bolus detector is described in the third experiment.)

Solid-state programing equipment was used to record lever presses and boli and to control delivery of reinforcers. Lever presses, reinforcer deliveries, and counts of boli detected were recorded on Gerbrands C3 cumulative recorders; automatic and manual counts of boli were entered in data logs after each session. A three-channel event recorder was used to record bolus droppings classified into those that occurred three seconds or less before a lever press, those occurring within three seconds after a lever press, and those occurring in the remaining portion of time.

Experimental Procedure

All sessions lasted 30 minutes and occurred within the first six hours of the daily 12-hour light period, with a few exceptions. Initially, each rat received two to four days of magazine training and hand shaping to press the lever on a fixed-interval one-second (FI 1-sec) schedule—virtually a continuous reinforcement schedule (CRF). After this initial training, each rat was exposed to an A-B-C-A-C-A sequence of schedules, where A was three or four sessions of FI 1-sec, B was three sessions comprising one session each in the progression, FI 4-sec, FI 8-sec, and FI 16-sec, and C was seven or eight sessions of FI 32-sec. For one rat (P4), the final series of FI 1-sec sessions (Series A) was extended to seven sessions for a direct comparison with the preceding seven sessions of FI 32-sec (Series C). Although no new schedule was introduced until the operant had stabilized, fewer sessions of stable FI 1-sec performance were run than other schedules because this reinforcement-dense schedule rapidly tended to result in body weight increases beyond the 90% deprivation weight.

Following the A-B-C-A-C-A sequence of fixed-interval schedules, a D-A sequence was added for three food-deprived rats, and three water-deprived rats who were randomly selected from each group of six. Series D consisted of seven sessions on a variable interval schedule of 32 seconds average (VI 32-sec), with a 2-second minimum and no maximum interval; it was achieved by sampling a probability gate every two seconds with the probability set at .0625. The final condition (A) was four or five sessions of FI 1-sec. The same reinforcers were delivered throughout.

Results

Cumulative Defecation

The sequence of procedures used and boli dropped are depicted in Figure 1 for all twelve rats. For Rats P1-P6 (P represents pellet), food was the reinforcer, and for Rats W1-W6, water was the reinforcer. Each unit on the abscissa represents one 30-minute session, and curves represent boli dropped per session, cumulated within each session and for all like schedule sessions in a series.

As is evident in Figure 1, high rates of defecation were mainly induced on FI 32-sec and VI 32-sec. Upon exposure to the novel apparatus, six of the twelve rats did not defecate. Three of the pellet-reinforced (PRF) rats (P1, P2, and P4) dropped only one bolus each during the first session; one of these three rats (P1) and a fourth rat (P3) dropped two to three boli during the second session. No PRF rat defecated during the last training session. The two water-reinforced (WRF) rats who defecated during training dropped two boli each during all training sessions. One rat (W1) dropped these during the third training session, and the other rat (W2) dropped them during the first.

The training sessions were followed by three or four sessions during which an FI 1-sec schedule was in effect, and there was no defecation for any of the six PRF rats nor for four of the six WRF rats. The remaining rats, W4 and W3, dropped comparatively few boli on FI 1-sec.

One session each at FI 4-sec, FI 8-sec, and FI 16-sec followed and none of the twelve rats dropped any boli during the FI 4-sec session. Three of the rats (P5, P6, and W4) dropped three boli each during the FI 8-sec session. Four rats (P2, P5, P6, and W4) dropped two to five boli each during the FI 16-sec session.

During all the FI 32-sec sessions, the PRF rats defecated markedly and defecation was typically absent during the FI 1-sec sessions that followed each FI 32-sec series. For the three PRF rats for whom VI 32-sec was added, defecation increased, from 4.0 boli dropped per session on the FI 32-sec schedules to an average of 6.6 boli dropped per session of VI 32-sec. The WRF rats defecated more often than did the PRF rats in the FI 1-sec sessions and defecated less than PRF rats in the FI 32-sec and VI 32-sec sessions. For the WRF rats, there was no corresponding increase over FI 32-sec when VI 32-sec sessions were added.

Defecation also appeared to be sensitive to schedules of daily running. On the second day of the first FI 32-sec series, all sessions for PRF rats were unavoidably delayed for six hours.

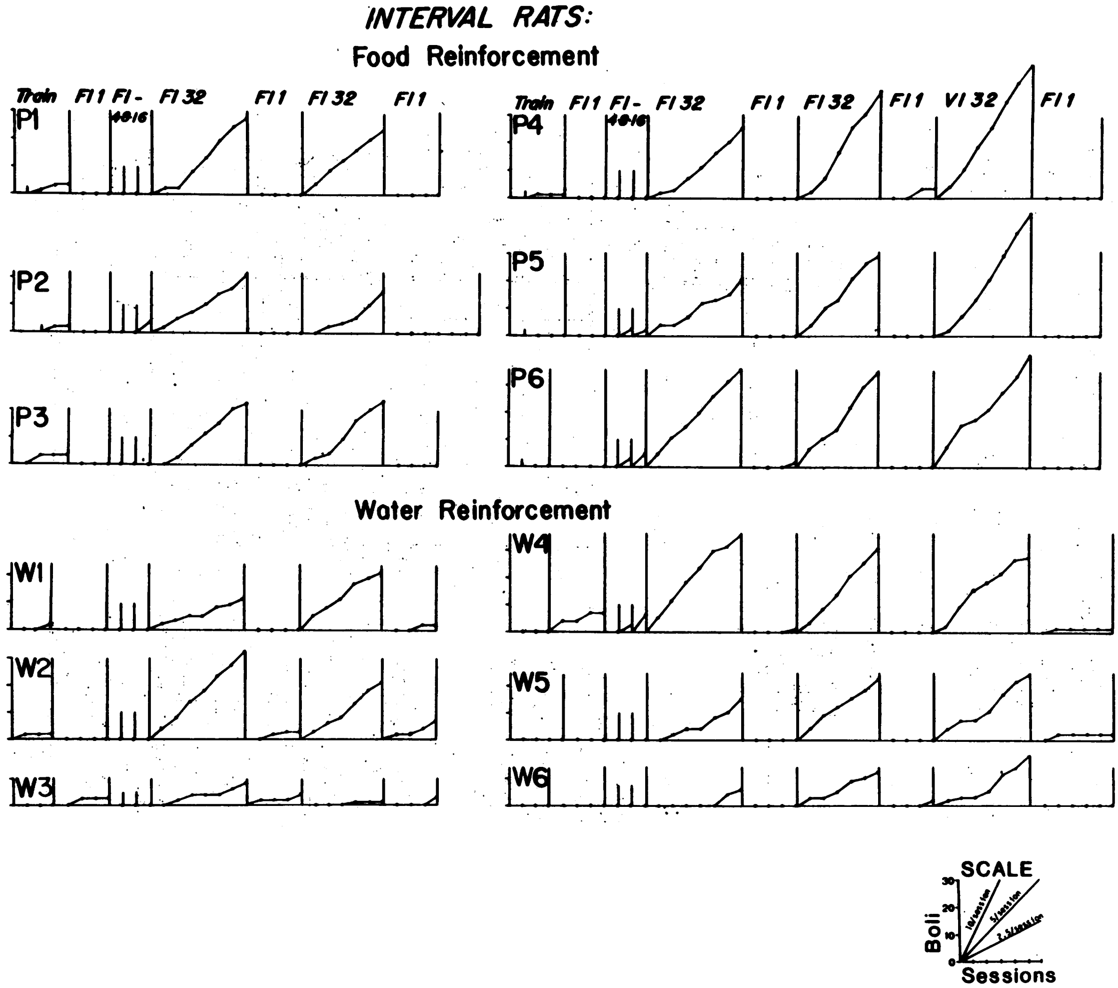

Fig. 1. Number of fecal boli dropped each session cumulated over each experimental treatment period for rats pressing a lever on various interval schedules of reinforcement with delivery of food (upper panels) or water (lower panels) as a reinforcer.

Rats P1 and P5 did not defecate at all, and Rat P4 dropped only one bolus. These days contrast with the other days on FI 32-sec. This was not apparently due to simple stimulus change. Usually the schedule of reinforcement was the prime determinant, not changes of schedule. Rats introduced to FI 32-sec schedules following an FI 1-sec series defecated during the first session of each series and thereafter at the high rate that characterized that schedule, and when introduced to the first FI 1-sec session following an FI 32-sec series, did not defecate at all—the characteristic pattern of that series.

Distributions within Sessions

Each 30-minute session was divided into 10 consecutive periods of three minutes each, and the number of boli detected by the photocell during each period was recorded. These data are presented for all twelve rats during all FI 32-sec sessions in Figure 2. For four of the six PRF rats, defecation tended to be maximal during the first three-minute period. For the remaining two PRF rats, peak defecation was either in the second or third period (minutes four through nine), and the distributions seem flatter. These two rats (P2 and P3) generally displayed less overall defecation than did the other four, as is evident in Figure 1.

Of the six WRF rats, on the other hand, only one rat (W2) defecated most during the first three-minute period; two rats (W4 and W5) defecated most in the second period. The

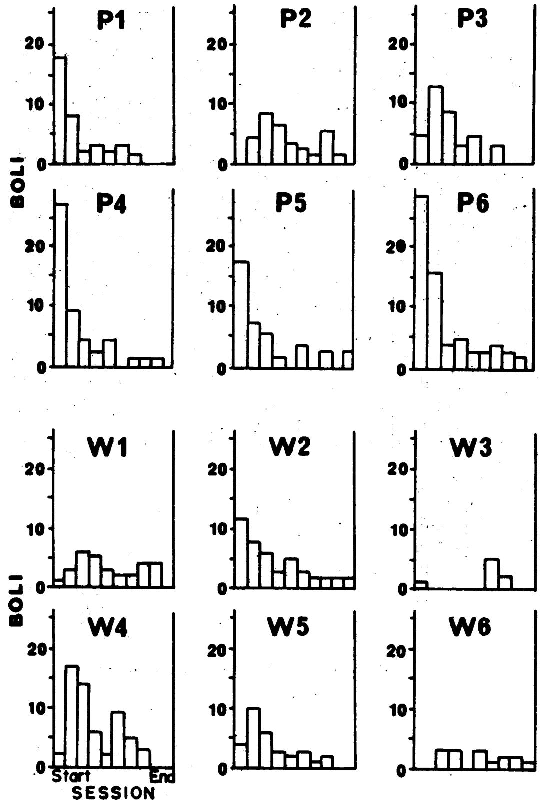

Fig. 2. Temporal distribution of fecal boli dropped within all sessions at FI 32-sec for each rat. Sessions are divided into ten consecutive 3-min periods. In the upper six panels, lever pressing was reinforced by food and in the lower six panels, by water.

distributions of the remaining rats are difficult to characterize. Those WRF rats whose distributions seem most similar to those of the PRF rats (W2, W4, and W5) also were the most similar to the PRF rats in terms of the overall defecation presented in Figure 1.

Similar distributions for variable-interval sessions for the three PRF and three WRF rats are presented in Figure 3. For all the PRF rats, defecation shifted markedly to the first three minutes of the 30-minute session. However, for the WRF rats, the practically flat distributions demonstrate a more even distribution of defecation throughout the session. In the PRF group, the distributions of Rats P4 and P5 are more skewed to the first period than for Rat P6, and overall defecation was least for this rat. It may be recalled that defecation by PRF rats was greater during VI than during FI sessions, whereas for the WRF rats such increase was not found. Apparently, temporal patterns of defecation appeared relatable to amount of defecation; rats who defecate more under one schedule than another will also tend to defecate earlier on that schedule.

For PRF rats which defecated frequently, those boli that were dropped late in the session tended to be looser, wetter, and in some cases more diarrheic than did those boli dropped early in the session. In Figure 3, a smaller peak of defecation later in the sessions can be seen for several rats. This may be due to the movement of a second portion of fecal matter through the colon and the small intestine.

Temporal Relation to Reinforcement and to Lever Pressing

Schedule-induced polydipsia tends to occur immediately after reinforcement, often during a postreinforcement pause (Falk, 1961, 1964). However, no such relation could be observed for defecation. For all six PRF rats, the 32-second interval during FI 32-sec schedules was subdivided into quartiles. Only 16% of the total number of boli were dropped during the first eight seconds following reinforcement, 23% were dropped during the second quartile, 32% during the third, and 29% during the fourth. Distributions for the individual animals were in line with these group data. Data similarly grouped for all six WRF rats on FI 32-sec were 26% for the first quartile; 22% for the second; 25% for the third; and 27% for the fourth.

The data with regard to relation to lever

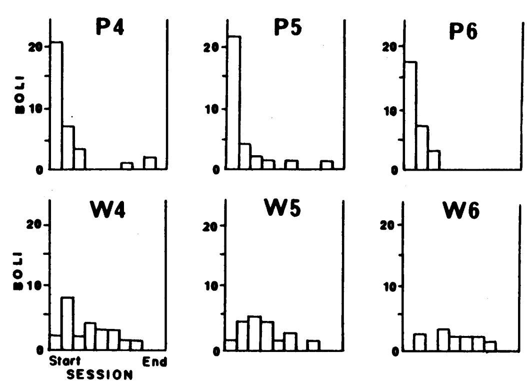

Fig. 3. Temporal distribution of fecal boli dropped within all sessions at VI 32-sec for each rat run on this schedule. Sessions are divided into 10 consecutive 3-min periods. In the upper row, lever pressing was reinforced by food and in the lower, by water.

pressing are similar. For all six PRF rats, 52% of the boli were dropped at a time later than three seconds after a lever press and earlier than three seconds before a lever press. 38% of the boli were dropped within three seconds before a lever press, and 20% were dropped within three seconds after a lever press. (Percentages add to more than 100% as some boli were dropped both within three seconds after a response and three seconds before the next response.)

Cumulative records of lever pressing were obtained for each session, with bolus dropping indicated by the event pen. The cumulative records obtained were similar to cumulative records of operant behavior obtained in other experiments and reported as "characteristic" of the schedules. The FI curves displayed the "scallops" characteristic of this schedule, and the VI curves displayed a steady rate of lever pressing. The clustering of fecal matter at the beginnings of the session was evident. Schedule-induced defecation did not interfere with the rate or pattern of lever pressing established under an operant schedule related to it.

Brief Discussion

The induction of defecation by FI 32-sec and VI 32-sec schedules is a robust effect, occurring in the large majority of subjects and with at least two different reinforcers. Such defecation was reliably and promptly halted or produced by introducing a CRF or FI/VI 32-sec schedule, respectively. The negative correlation of amount of defecation to number of reinforcers consumed is particularly striking. Although the schedules that induced it were temporal, regularity of reinforcement in time alone appeared not to be the critical variable since defecation was also induced on VI 32-sec and was even enhanced thereby.

EXPERIMENT 2 DEFECATION DURING FIXED RATIO SCHEDULES WITH FOOD REINFORCERS

The first experiment demonstrated that defecation was induced when rats are lever pressing for food or water on temporal schedules such as FI 32-sec and VI 32-sec but not on shorter temporal schedules such as FI 1-sec. In both FI and VI schedules, reinforcer delivery is contingent upon the passage of time as well as upon the specified response. In FI, distribution of responses within the interval is irrelevant to the schedule. However, since the intervals vary in VI, reinforcement density is maximized by intervening responses. The contributions of intervening responses and time interval were experimentally separated in the following manner. In the second experiment to be reported here, the 32-sec time interval of FI 32-sec was nearly preserved, but by means of a fixed ratio schedule. Given a steady response rate, an *n*th response may be found empirically that occurs approximately 32 sec after reinforcement, and reinforcement may be made contingent on that *n*th response in a FR-*n* schedule. Although the FI 32-sec time interval is preserved, *n*-1 intervening responses are required for the counter to record *n* and deliver the reinforcer, which is not the case for FI 32-sec. In the third experiment (to be reported subsequently) delivery of food was made contingent on the completion of a timer cycle alone, irrespective of behavior.

Method

Subjects

Subjects were three experimentally naive male albino rats of the same strain, same weight range (289 to 308 g), and same age (90 days) as the rats in Experiment 1. Housing and food-deprivation conditions and procedures were also similar.

Apparatus

The chamber with pellet dispenser used in the first experiment was also used for the second. Control, monitoring, and recording equipment were also the same.

Procedure

As before, all sessions lasted 30 minutes. Lever pressing was hand-shaped with a food pellet following each response (FR-1). Each rat was then presented with an ascending series of fixed-ratio requirements. There were four sessions each of FR-1, FR-2, FR-4, and FR-16, during each of which response rate and pattern stabilized. However, when the ratio requirement was increased to FR-32 and beyond, lever pressing by all rats did not stabilize in four sessions. Accordingly, additional sessions were run in a series on an individual basis until stability was obtained. The sole exception to this procedure was for one series, with one rat (R3, first FR-64 series), when eleven sessions were run with no improvement in stability, and the next schedule was introduced. The ratios following FR-32 were FR-64, FR-80, FR-96 for all three rats. Two of these rats were also run at FR-128, and one of these was also run at FR-192. For each rat, a series descending from the highest ratio to FR-1 was then run. This was followed by another ascending series and then a descending series. Two rats were then run on single sessions of FR-1, FR-192 or FR-96, and FR-1.

Results

The actual sequence for each rat, the number of sessions at each ratio series, and the cumulative number of boli dropped during each series are presented in Figure 4. The numbers in italics indicate the average time in seconds between reinforcements in that series; differences between reinforcement rates at the same ratio represent differences in overall response rate.

Cumulative Defecation

Rat R1 (R as in Ratio) almost never defecated during experimental sessions. He did not defecate at FR-96, when the rate of responding produced interreinforcement intervals (IRI) of 32 seconds. He did not defecate during any sessions ranging from FR-1 to FR-192 thereafter, except for one bolus dropped during the first FR-192 series (IRI 79 seconds) and one bolus during the FR-32 series (IRI 13 seconds).

Rat R2, as well, almost never defecated on schedules ranging from FR-1 to FR-96. He did not defecate during the first FR-48 series when the IRI was 28 seconds, nor the following FR-64 series when the IRI was 39 seconds. The only boli he dropped were one in the second FR-8 series, and one during the fourth FR-16 series.

Rat R3, in contrast, dropped more boli than other ratio rats. Defecation was not systematic or reliable, nor was the rate as high as that induced on the FI 32-sec schedule in Experiment 1. He dropped three boli during the first training session, and none thereafter until the fifth session on FR-64. On this schedule, he pressed the lever about twice per second, resulting in an IRI of 38 seconds. He then continued to defecate through the FR-80 series (IRI 58-seconds), dropping an average of 5.2 boli per session. He defecated less during the FR-96 series, dropping an average of 3.5 boli per session. During the following FR-128 series, defecation decreased further and finally ceased. Rat R3 did not defecate when these schedules (FR-64, 80, 96, and 128) were reintroduced. It will be recalled that, in contrast, during those interval schedules when defecation was found to occur, rats defecated whenever those schedules were reintroduced.

The performance of Rat R3 is anomalous in other regards as well. Cumulative records of lever pressing for all three rats reflected typical fixed-ratio performances. The fixed-ratio patterns of Rat R3 were the least stable of the three rats, exhibiting the greatest number of those pauses commonly associated with ratio strain. Rat R3 was also the only rat under a ratio schedule which defecated during the initial training period. For Rat R3, no systematic relation was found between defecation and either reinforcement or lever pressing.

Distribution of Defecation within Sessions

The distribution of boli dropped by the only rat who defecated significantly on ratio schedules is presented in Figure 5. The boli dropped during the first FR-64, FR-80, FR-96, and FR-128 series were recorded in ten 3-min bins for all 30-min sessions, as before. This distribution differs considerably from the distributions produced under FI 32-sec by food-reinforced rats (Figure 2). There is no peak at the beginning of the session, nor is there a noticeable tendency to drop boli at any other particular time during the session.

Brief Discussion

It appears that defecation is not generally induced by fixed ratio schedules. Where it did appear in one rat, it turned out to be a transient phenomenon; it did not recur when the same ratio requirements were introduced at a later time. This contrasts with defecation under interval schedules, in which it was reliably and repetitively induced when schedules with which it is associated were repetitively introduced and was reliably and repetitively eliminated when schedules associated with its absence were repetitively introduced.

The induction of defecation under both FI and VI schedules (Experiment 1) suggests that regularity of interreinforcement intervals is

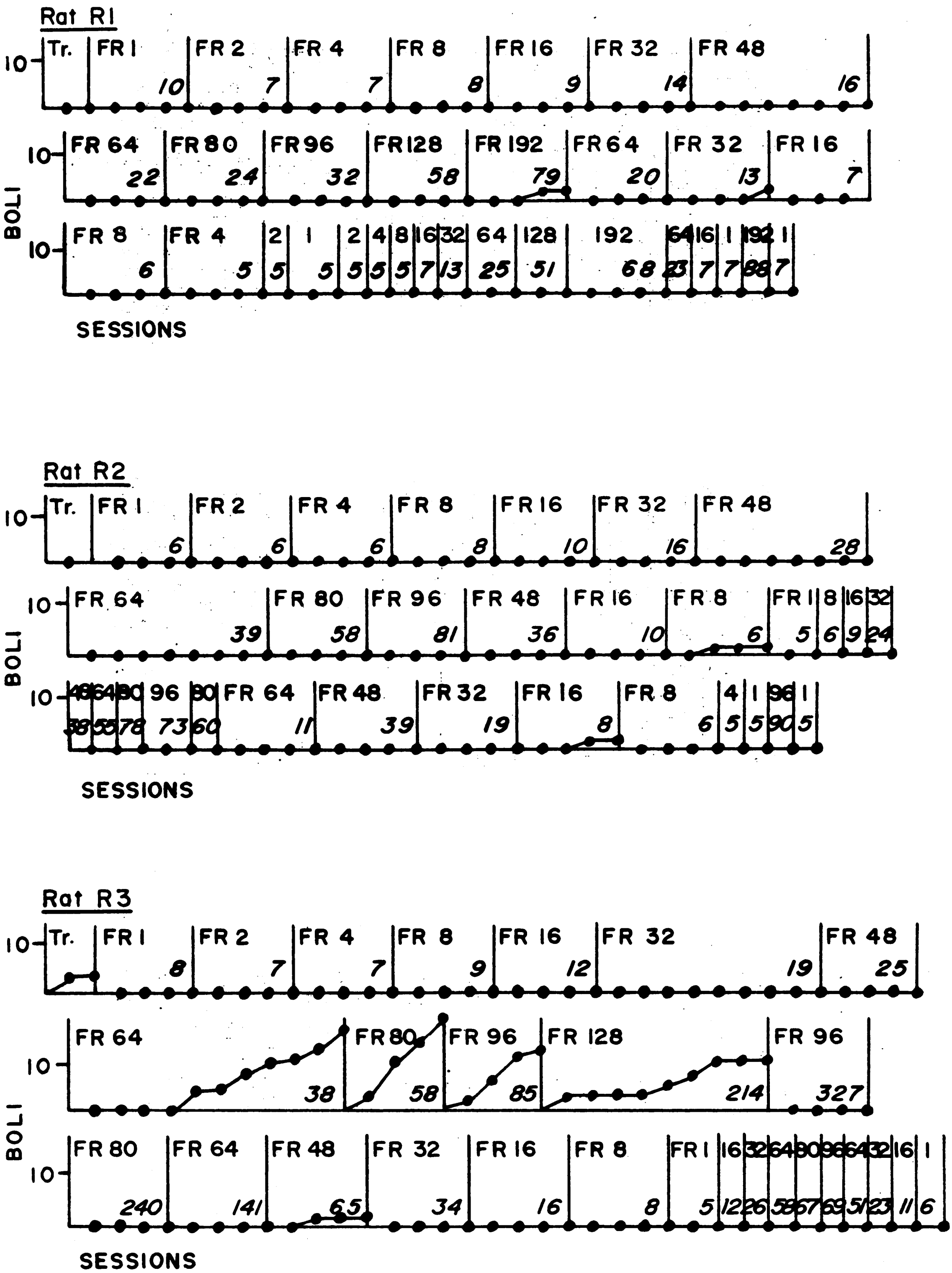

Fig. 4. Number of fecal boli dropped each session cumulated over experimental treatment periods for rats pressing a lever on various fixed-ratio schedules of reinforcement (see Figure 1). Number in italics is the time (in seconds) interval between deliveries of reinforcement, averaged for each treatment.

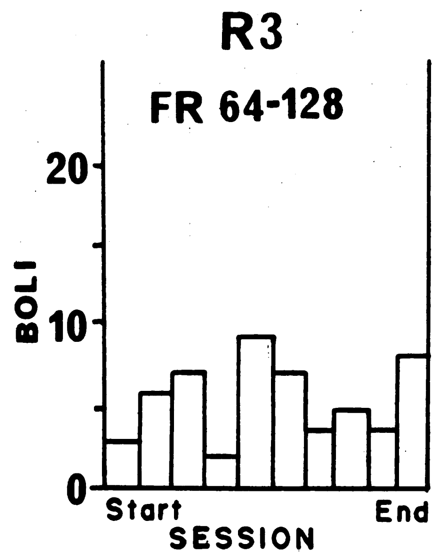

Fig. 5. Temporal distribution of fecal boli dropped for the rat who did defecate within all fixed-ratio schedules during which defecation occurred. Sessions are divided into 10 consecutive 3-min periods (see Figure 2).

not essential to schedule-induced defecation. Nor is the steady-state regularity of response rate during VI essential to schedule-induced defecation since defecation was not induced under the regular responding of FR schedules and was induced under scalloped FI responding.

EXPERIMENT 3
DEFECATION INDUCED BY FIXED TIME SCHEDULES WITH FOOD REINFORCERS

In the first experiment, defecation was induced when food or water was contingent on lever pressing under reinforcement schedules such as FI 32-sec or VI 32-sec, but not at lower interval schedules such as FI 1-sec. In the second experiment, defecation was not induced accompanying FR schedules in which the intervals between reinforcements were similar to those found in the defecation-inducing FI schedules. The differences between defecation-inducing temporal schedules and interval-comparable noninducing FR schedules may rest in the different type of behavior contingencies holding. On the other hand, they may simply rest in the difference between presence and absence of time-dependent interreinforcement intervals. Defecation, like polydipsia, might be induced simply by delivering food pellets at temporal intervals comparable to those hitherto sufficient for induced defecation. Such timer-governed delivery of food pellets is defined as a fixed-time (FT) schedule, in contrast to fixed-interval (FI) schedules where the timer governs availability of food, and a subsequent experimenter-defined response is required to deliver it. Experiment 3 compared induced defecation on FT 32-sec, FI 1-sec, and FI 32-sec.

METHOD

Subjects

Six rats served. Four were experimentally naive male albino Holtzman rats of the same strain, weight range (303 to 306 g), and age (90 days) as the rats in Experiments 1 and 2. Two were experimentally naive female albino Sprague-Dawley rats, of lower body weights (259 and 280 g), and same age (90 days) as the males. Housing and food-deprivation conditions and procedures were also similar to the previous experiments.

Apparatus

The chamber with pellet dispenser used in the first and second experiments was also used here. A lever was present in most conditions, but was unrelated to food delivery in the FT conditions. It was removed from the chamber during one FT condition. Control, monitoring, and recording equipment were the same as in previous experiments, except for variations in lever presence and lever contingencies, as noted, and except for the substitution of a new bolus detector.

A square piece of 20 gauge aluminum served as a drop-pan under the entire chamber floor, and an inexpensive ceramic phonograph cartridge was mounted on it. The drop pan rested on foam rubber feet at each of the four corners and was positioned 15 cm below the chamber floor. The phonograph cartridge was connected to an LM324 operational amplifier, which served as an adjustable trigger. With this detector it was possible to set the trigger to ignore urine droppings, but to record virtually all boli dropped.

The new bolus detector detected 98% of boli dropped, in contrast to the 80% detected by the earlier one.

Cumulative records were kept of lever pressing in each session (whether the lever was functional or not), as well as counts of lever presses, food-pellet deliveries, and boli dropped. As previously, hand counts of boli were taken to verify and supplement automatic bolus detection.

Procedure

All sessions lasted 30 minutes, as before. For the four male rats (T1 to T4), the first block consisted of ten sessions in which a 37-mg food pellet was automatically delivered every 32 seconds (FT 32-sec). The second block consisted of four or five sessions of FI 1-sec. Hand shaping of lever pressing occurred during the first FI 1-sec session but required only five to ten minutes of the 30 min session. Upon completion of the second block, two rats (T2 and T3) were withdrawn from the experiment in order to be used in a different one. For the two remaining, the ensuing design involved alternating blocks of seven or eight FT 32-sec sessions with blocks of seven or eight FI 32-sec sessions. The lever was removed for the final FT 32-sec series for both rats. The order and number of sessions in each series is shown in Figure 6.

The two female rats (T5 and T6) each received ten sessions of FT 32-sec. The experiment was then interrupted for 79 days, during which the rats were fed and watered ad lib. They were then deprived to 90% body weight. For Rat T5, FT 32-sec was continued for 18 sessions, followed by four sessions of FT 256-sec. For Rat T6, deprivation was followed by 22 sessions of FT 32-sec.

RESULTS

The detailed sequence for each rat, the number of sessions at each series, and the number

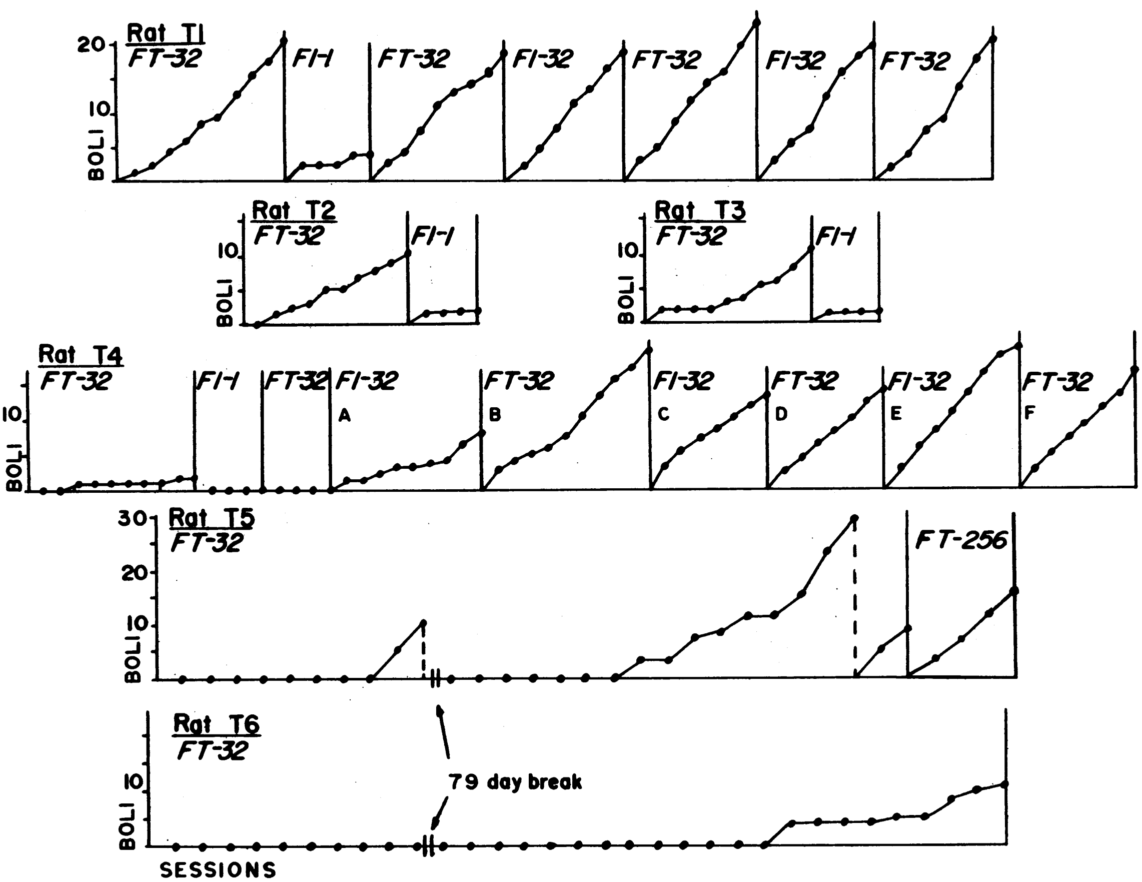

Fig. 6. Number of fecal boli dropped each session cumulated over each experimental treatment period for all rats to whom food was presented at fixed-time periods (FT 32-sec), or for whom food was available at similar (FI 32-sec) temporal intervals, or those lower (FI 1-sec), but with a depressing of a lever then necessary for food delivery (see Figures 1 and 2).

of boli dropped per session cumulated for each series are presented in Figure 6.

Cumulative Defecation

For Rat T1, boli were dropped during FT 32-sec and FI 32-sec, in almost indistinguishable patterns or rates. In contrast, once lever pressing was established, there was little defecation during the FI 1-sec sessions. In all the following FT 32-sec series and FI 32-sec series, defecation resumed at high rates. Removal of the lever in the terminal FT series had no discernible effect on defecation.

For Rat T2, the difference between FT 32-sec and FI 1-sec was even more pronounced. The FT 32-sec produced regular, moderate defecation. The FI 1-sec series was characterized by no defecation except during the FI 1-sec training session.

Rat T3 dropped four boli in the first FT 32-sec session, did not defecate during the next three sessions, and then resumed defecating for the rest of the FT 32-sec sessions at a rate comparable to Rats T1 and T2. Like Rat T1, he defecated infrequently (two boli) during the first (and only) training session, and did not defecate during the three FI 1-sec sessions thereafter.

Rat T4 dropped only two boli during the ten sessions of the first FT 32-sec series. No boli were dropped during the three FI 1-sec and four FT 32-sec sessions that followed. Regular defecation began in the next series, FI 32-sec. Thereafter, defecation in FT 32-sec and FI 32-sec sessions replicated the patterns of the other three male animals on these schedules. Similarly, removal of the lever in the last FT 32-sec series had no discernible effect on defecation.

After eight sessions of no defecation, Rat T5, a female, defecated during two sessions of FT 32-sec. After a break of 79 days, the FT 32-sec series was resumed. The previous pattern was almost replicated: there were seven sessions without defecation, with defecation occurring thereafter. The rate of defecation increased gradually, with eight boli dropped during Session 25. A series of four FT 256-sec sessions was then run with no decrease in defecation.

For Rat T6, like T5, early sessions were devoid of defecation. There was no defecation during the ten sessions preceding the 79 day break, nor during thirteen sessions on FT 32-sec that followed. Thereafter, modest defecation began.

Distribution of Defecation within Sessions

Each 30-minute session was divided into 10 bins of three minutes each, and the number of boli dropped during each three-minute unit was recorded. The distributions for Rats T1 to T6 are presented in Figure 7. The distributions of defecation for rats on FT 32-sec did not differ appreciably from distributions seen on FI 32-sec in this experiment and in the first experiment. For Rat T1, all four FT 32-sec series are combined. The concentration of bolus droppings (35% of the total) during the first three minutes is marked; the distribution seems to have an additional pair of progressively smaller peaks thereafter. That the overall data are typical of individual series can be seen by comparison with the distribution of the first FT 32-sec series alone in the adjacent distribution. About 40% of the boli were dropped in the first three-minute period, and there are two "peaks" thereafter. The distribution for all the FI 32-sec series for this rat does not appreciably differ: about 28% of all boli were dropped in the first three minutes of all FI 32-sec sessions with two "peaks" thereafter.

Rat T2 dropped too few boli in any period to describe any characteristic distribution with confidence. However, Rat T3, even with a limited number of sessions, displayed a "peak" during the first three minutes, when about 40% of the boli were dropped.

For Rat T4, the distribution for all four FT 32-sec series combined is presented; 23% of all boli were dropped during the first three minutes, and an additional 30% were dropped in the next three, with over half of the boli (54%) accounted for during the first six minutes of the 30-minute session. The individual distributions for each FT 32-sec series (except the first series, which produced only two boli) similarly display an increasingly marked peak in either the first or second three minutes as seen in Distributions B, D, and F. The first FI 32-sec series for this rat was characterized by very little defecation (see Distribution A), but as defecation increased during the second and third FI 32-sec series (Distributions C and E), the typical "peak" became evident early in the session.

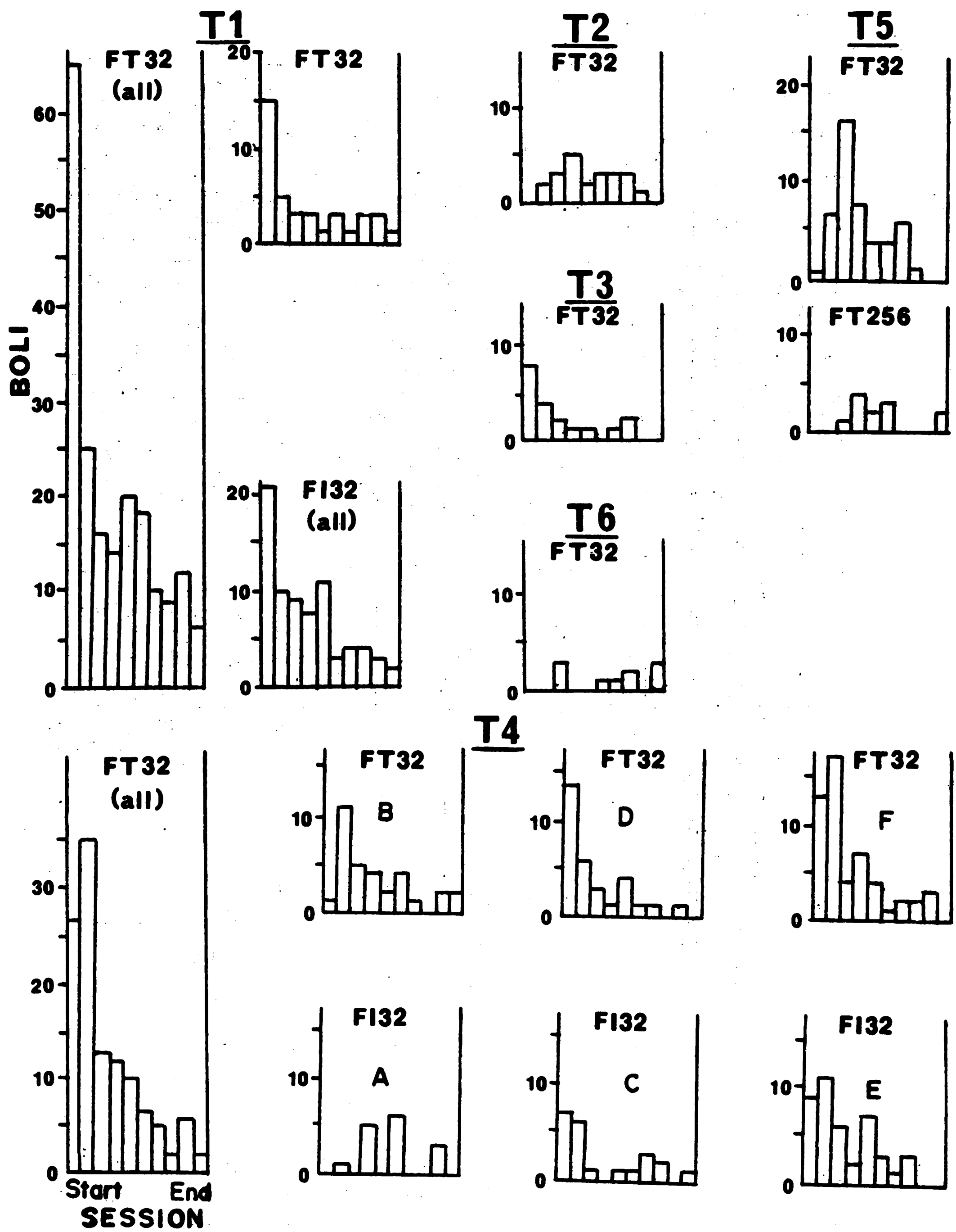

Fig. 7. Temporal distribution of fecal boli dropped within FT 32-sec and FI 32-sec series for each rat. Sessions are then divided into 10 consecutive 3-min periods.

The distribution of boli dropped by female Rat T5 is also marked by a "peak" early in the session—centered, however, in the third three-minute period (35% dropped that period). Again, there is mild evidence for a second peak. The number of boli dropped by this rat during sessions on FT 256-sec, as shown, is insufficient to ascribe any particular pattern. The other female, Rat T6, defecated so infrequently that no statements can be made about her distribution.

Temporal Relation to Reinforcement and Lever Pressing

No temporal relation between the delivery of food pellets and defecation was observed for any of the subjects in this experiment. Similarly, there was no observable relation of defecation to lever pressing. For example, the first series for Rat T1 was an FT 32-sec series. The operant level of lever pressing for each day in this series decreased from 42 to about 5 per session. Defecation appeared to be unrelated to those lever presses. An FI 1-sec requirement was then imposed on the free-operant level. When FT 32-sec was reintroduced, the lever was again nonfunctional. The number of lever presses for each of the FT 32-sec sessions was 151, 50, 42, 32, 20, 11, 15, and 23, with the initially highest rate probably reflecting the historical effects of the preceding fixed-interval sessions, and the decreasing rates thereafter reflecting extinction of the response under an FT schedule. The first FI 32-sec series followed, and typical scalloped lever pressing was quickly established. During the next FT 32-sec series, the number of lever presses per session was 195, 134, 114, 167, 74, 109, 86, and 82, again reflecting both history and extinction. No lever was present during the final FT 32-sec series. In no condition could the experimenter detect a relation between defecation and lever pressing.

For Rats T2 and T3, there also appeared to be no relation between free-operant lever pressing and number of boli dropped per session. For example, the operant levels of lever pressing during FT 32-sec series (and number of boli dropped per session in parentheses) were 26(0), 8(3), 17(2), 28(1), 41(0), 18(3), 26(4), 14(2), 14(3), and 27(4), 23(0), 17(0), 29(0), 16(2), 27(1), 30(4), 25(1), 16(4), 16(5), respectively. For Rats T5 and T6 the number of free-operant lever presses was less than 20 during each session of FT 32-sec. These, too, appeared unrelated to defecation.

Finally, subjects were observed in some cases to lever press and defecate simultaneously.

Brief Discussion

Frequency of defecation under the fixed-time schedules used, once started, did not differ appreciably from that holding under fixed-interval schedules with identical time parameters. The distributions of defecation within an FT session were also similar to those seen in an FI session, displaying the same high peak early in the session, followed by smaller peaks thereafter.

The major difference between time and interval schedules seemed to be in the number of sessions required for defecation to start. This statement holds especially for three rats (T4, T5, T6) and possibly a fourth (T3). In Experiment 1, involving only interval schedules, the onset of defecation was also delayed for many rats, especially those whose reinforcement was water. The differences in onset between time and interval performances appeared, then, to be one of degree. Once established, the pattern seemed to be strong in either case.

EXPERIMENTS 1 TO 3 OTHER OBSERVATIONS OF SUBJECTS' BEHAVIOR

Defecation has been related to emotionality in the general literature. Accordingly, the behavior of the rats outside of the experimental chambers and within them is worthy of note.

Housing

Rats defecated freely in their home cages. The litter was changed every three days, and boli were counted. In the male housing units, an average of 25 to 30 boli per rat was found for each day. In the females' cages, the corresponding average was about 18 to 25 boli. During sessions, when defecation was induced, rats generally dropped between 3 to 6 boli, although as many as 12 boli were dropped in one session. Boli dropped later in a session tended to be extremely moist and unformed. Diarrhea was observed in many cases. On days when defecation-inducing schedules were in effect (FI 32-sec, VT 32-sec, FT 32-sec), from about 12% to 50% of a rat's daily boli were dropped during the 2.1% of the day represented by a 30-minute experimental session.

General Disposition

The demeanor of the rats was seldom aggressive. Rather, when the experimenter approached the home cages to transport a rat to the experimental chamber, all rats immediately crowded to the front of their units, raising themselves and poking their noses through the bars. They scrambled over each other to climb into the experimenter's hand. Once there, if released, they climbed over his arm or explored him in other ways. After weighing, the rats hopped out of the pan with alacrity. As the experimental chamber was approached, they struggled to escape the experimenter's hand and to enter the chamber. At the end of the session when the experimenter reached his hand into the chamber to remove the rat, the rat would typically cling to the mesh floor or mesh wall furthest from the experimenter's hand. No rat ever bit the experimenter at this time.

Emotionality

The rats were observed and photographed during sessions when they defecated and at other times. There were none of the responses from which emotionality is generally inferred: there was no piloerection, rigidity, crouching, nor suppression of lever pressing. As previously noted, rats occasionally defecated while pressing a lever (and have been photographed). Such behavior was not uncommon, especially during sessions of VI 32-sec, but the majority of the boli were dropped while the animal was eating, grooming, or exploring. None of these activities is compatible with an inference of emotionality.

GENERAL DISCUSSION

We report in these experiments the systematic induction of a pattern of behavior which, when reported elsewhere, has generally been assigned to emotionality under stressful conditions. The conditions so labeled have been either initial exposure to a novel situation, such as the "open field" test (e.g., Hall, 1934), or the presentation of an aversive or preaversive stimulus. In our experiments, defecation was induced during ordinary schedules of reinforcement in the absence of either the conditions associated with stress or other responses assumed to indicate it. As judged by the demeanor of our rats, the experimental chamber was not a place of stress, nor was it a condition that occasioned avoidance behavior. The rats did not, as they typically do in CER experiments, withdraw to the back of their home cages when approached, nor struggle against being picked up, nor bite the extended hand of the experimenter, nor fight being placed in the experimental chamber. The behavior of the rats run in our experiments was the opposite. Yet they defecated, and often profusely, in the experimental chambers when under those schedules often used to maintain baseline responding in conditioned suppression (CER) experiments. Their defecation was not accompanied by rigidity, piloerection, nor other responses presumably related to stress. Indeed, very little defecation occurred during their initial exposures to the novel chamber, and such defecation as did then occur was not accompanied by the other emotional concomitants of the open field test. The question is raised as to the extent to which defecation as a sign of emotionality in a CER paradigm (as opposed to a reflex response to shock) is in part an adjunct to the reinforcement schedule used to maintain the operant whose suppression is being studied.

The defecation-inducing schedules of our experiments typify those used to induce polydipsia (Falk, 1961). The conditions under which one schedule-induced behavior is found rather than the other, or both, or neither, have not been investigated, nor are they the subjects of the research presented to date. It is also of interest that the schedules that do not typically induce polydipsia (fixed-ratio and low-fixed intervals) also do not induce defecation. However, the occurrence of defecation by Rat T6 under a few sessions of FT 256-sec suggests that defecation may continue to be induced by those long intervals under which polydipsia is attenuated.

It is clear that under the conditions of the experiments presented, deliveries of a stimulus made potent by deprivation are sufficient to produce defecation if the intervals between deliveries are governed by time, with (FI) or without (FT) an experimenter-defined response requirement for such delivery. A variety of activities occur during an experiment that are ancillary to the operant under investigation. Schedule-induced behavior may be one of these and, when it does come to attention, should not be assumed to be the only one of these. It may be the case that in an FT session, in which reinforcement is not contingent on an experimenter-defined operant but, rather, is strictly governed by a timer, behavior ancillary to the defined-as-unnecessary operant does systematically precede reinforcer delivery [possibly as defined by the organism; e.g., reaching for the experimenter-delivered reinforcer (cf. Skinner, on "chained reflexes," 1938, pp. 102-108)], thereby functionally reinstating an FI schedule (Note 1). Although the possibility requires experimental demonstration, it should, nevertheless, be noted that with regard to defecation, the interreinforcement spacing that induced defecation in fixed- and variable-interval schedules and fixed-time presentations did not induce defecation when the equally spaced deliveries were under the governance of previous responses, as in fixed-ratio schedules.

It appears that the defecation that is so induced is not simply the result of a gastrocolic reflex to food or water intake. If it were, it would have been expected all the more strongly under schedules such as FI 1-sec, as well as small fixed ratios, when rate of food intake was high. Under larger FR schedules, reinforcement density was often as low as it was under FI and VI schedules with deliveries similarly spaced. Nevertheless, there was not systematic defecation under the FR schedules, but there was such defecation under the temporal schedules (FI, VI, and FT). Therefore, a reflex to infrequent presentations of food to the alimentary canal is an insufficient explanation. Furthermore, although concentrated at the beginning of temporal sessions, defecation continued throughout the session, with each bolus becoming progressively softer. Several of the rats on FI 32-sec and VI 32-sec dropped diarrheic stools. These data are not consistent with an interpretation of the defecation as a normal gastrocolic reflex.

It has been argued that one characteristic differentiating the schedules or conditions inducing polydipsia from those not inducing it (which held for defecation in the present series) is the availability of free time for alternative activities. In the low interval schedules, this time is presumably occupied by lever pressing, as it is in the ratio schedules. It is under the temporal schedules of time presentations that animals may presumably find the time to engage in polydipsia, or defecation, or, for that matter, exploring the territory of another rat (Davis & Wheeler, 1966). However, as Falk noted (1961), and as can be observed from our cumulative records, time is available for alternative activities during the low FI schedules and on the ratio schedules. Further, the VI schedules may be as "crowded" with operant behavior as are FR schedules. Finally, the observation that defecation and lever pressing occurred simultaneously suggests that availability or lack of opportunity due to patterns of ongoing scheduled operants is not a plausible explanation.

By virtue of its association, possibly artifactual or reflexive, with stressful conditions and stress-suggestive behavior, excessive defecation has been considered to be a sign of stress. Accordingly, treatment of such human syndromes as the irritable colon syndrome has often been addressed to presumed stressful conditions or life styles and the emotional reactions that accompany them. To the extent that extrapolations may be made from the present experiments (as they have been from others), they suggest that schedules of positive reinforcement as they relate to temporal governance, may be involved. Indeed, Brady et al. noted some time ago (1958) that the "executive monkeys" whose lever pressing postponed delivery of shock for themselves, and their yoked controls succumbed from perforated ulcers only when specific time periods governed the instatement and withdrawal of the experimental nondiscriminated avoidance conditions.

The foregoing experiments are presented to report initial explorations and findings, rather than to be definitive. Research presently under way will report extensions to other schedule-induced patterns, to other schedules, and to other procedural parameters.

REFERENCE NOTE

1. The authors are indebted to Paul Andronis and T. Joe Layng for help in clarifying this point. Since the writing of this article, Rayfield has experimentally demonstrated scalloped responding of the type found in FI schedules, under FT schedules. The ancillary behavior recorded was nose or paw operation of a cover to the food magazine. A poster session of the experiment was presented at the 1981

annual meeting of the Association for Behavior Analysis, Milwaukee, entitled: Operant Responding on FT Schedules.

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