JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1989, 52, 167-179 NUMBER 2 (SEPTEMBER)

VARIABLE-RATIO CONDITIONING HISTORY PRODUCES HIGH- AND LOW-RATE FIXED-INTERVAL PERFORMANCE IN RATS

BARBARA A. WANCHISEN, THOMAS A. TATHAM, AND SUSAN E. MOONEY[1]

BALDWIN-WALLACE COLLEGE AND MOUNT UNION COLLEGE

Four rats were exposed to an A-B-A-B series of 30 sessions each of variable-ratio 20 (A) and fixed-interval 30-s (B) schedules. Four other rats received 120 sessions of fixed-interval 30 s. The rats with a history of variable-ratio responding subsequently showed primarily high or low response-rate patterns on the fixed-interval schedule without evidence of classical scalloping (i.e., increased rates of responding throughout the interreinforcement interval), except infrequently in 1 rat. The rats exposed to only the fixed-interval 30-s schedule displayed the expected sequence of scalloping giving way to lower rate break-run or simply low-rate responding over time. This experiment shows that when naive rats are exposed to even a simple history of reinforcement (in this case, a variable-ratio 20), their subsequent fixed-interval performance is very different from comparable performance in naive rats, and might be said to be more similar to the responding of adult humans. The argument is made that care should be taken in comparing the fixed-interval performance of humans and nonhumans because humans have a complex history of reinforcement, whereas laboratory nonhumans are typically naive.

Key words: conditioning history, human/nonhuman differences, scallop, fixed-interval schedule, variable-ratio schedule, lever press, rats

The investigation of discrepancies between the behavior of humans and other animals on schedules of reinforcement has been a topic of lasting interest in the operant community. In order to explain these discrepancies, some have suggested that covert behavior (e.g., thinking) explains why humans behave differently than nonhumans (Lowe, Beasty, & Bentall, 1983). There are also more conservative accounts in which procedural differences, rather than fundamental differences in process, are advanced as explanations.[2] Most researchers who ascribe to the latter view do not find it implausible that new principles will be needed to explain human behavior, but do argue that new principles should be invoked only when all existing principles prove inadequate.

One area of focus for studying differences between humans and nonhumans has been the fixed-interval (FI) schedule in which reinforcement is made contingent upon one response after a certain amount of time has passed. It has been shown that response patterns typically vary markedly between nonhumans and adult humans (see Lowe, 1979).

Ferster and Skinner (1957) catalogued nonhuman performance on various FI schedules and found that, initially, the pigeon's response rate is negatively accelerated; that is, most of the responses occur immediately after reinforcement, in the beginning of each interval, with response rate decreasing throughout the interval. Within several sessions, responding settles into a pattern that resembles a scallop on a cumulative recorder as the interval times out. That is, after reinforcement, the subject does not respond very much and then the rate of responding increases gradually as the interval times out.

More recently, Dews (1978) suggested that a break-run pattern (postreinforcement pause followed by a high rate until the next reinforcer) can be an equally typical pattern in the same subject's record. After extended exposure

---

[1] B. A. Wanchisen and S. E. Mooney are at Baldwin-Wallace College; T. A. Tatham was at Mount Union College. This research was, in part, funded by a Cleveland Foundation Summer Grant, awarded to the first author. We thank Mark Yasenchack, Sylvia Palfalvi, and Marie Schmidt for analyzing the data, with additional thanks to Mark for preparing the figures. We also thank the Department of Psychology at Temple University for lending us the operant chambers, making this research possible. We appreciate the support provided by the Physics Department at Baldwin-Wallace College, especially Ken Jensen, who was instrumental in equipment design and repair. Correspondence and reprint requests may be sent to B. A. Wanchisen at the Department of Psychology, Baldwin-Wallace College, Berea, Ohio 44017, or T. A. Tatham, who is presently with the Department of Psychiatry at the Temple University School of Medicine, with the following mailing address: Department of Psychology, 13th & C. B. Moore, Temple University, Philadelphia, Pennsylvania 19122.

[2] Perone, M., Galizio, M., & Baron, A. (1987, May). *Schedule control of human and non-human behavior: How different?* Paper presented at the annual convention of the Association for Behavior Analysis, Nashville, Tennessee.

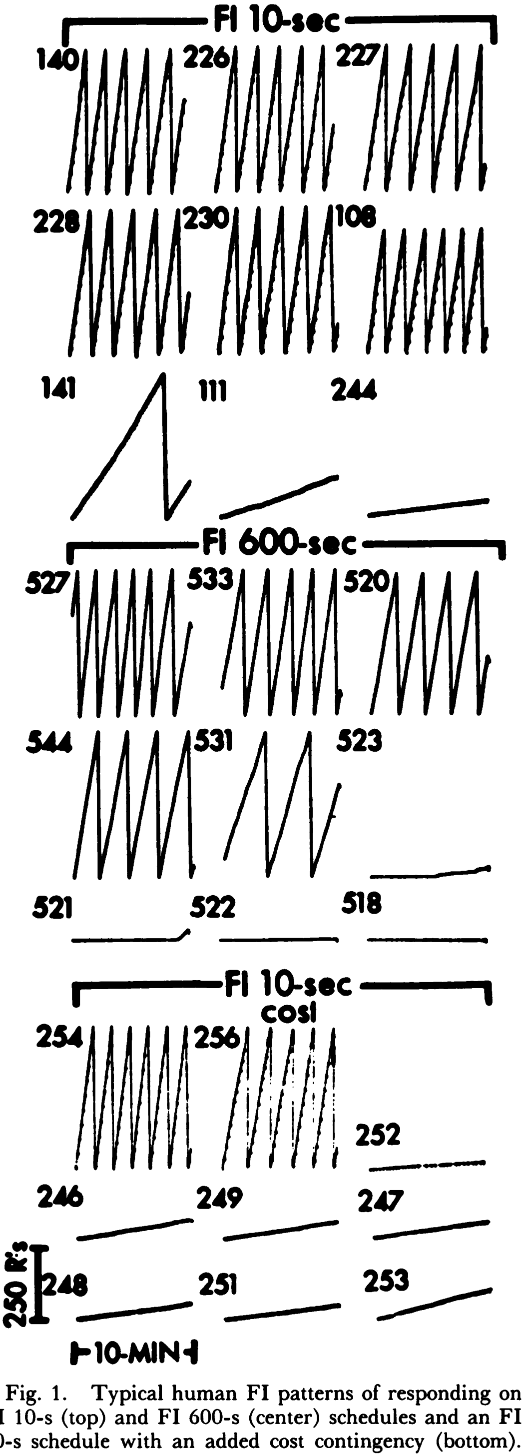

Fig. 1. Typical human FI patterns of responding on FI 10-s (top) and FI 600-s (center) schedules and an FI 10-s schedule with an added cost contingency (bottom). Note that humans either emit a very high- or low-rate pattern of responding without evidence of scalloping. Taken from Weiner (1969) and reprinted by permission.

to the FI with long session lengths, the scallop eventually gives way to the break–run pattern in which a postreinforcement pause is followed by a high rate of responding (the running rate) until reinforcement (Cumming & Shoenfeld, 1958; for microanalyses, see Dews, 1978; Gentry, Weiss, & Laties, 1983; Schneider, 1969). Although it is accurate to say that the scallop and/or the break–run pattern are typical in nonhuman performance, the scallop is typically cited as the dominant FI response pattern.[2]

In addition to a predictable temporal pattern of responding in nonhumans, there are orderly relationships between FI size and various dependent variables. For example, as FI size increases, running rate and overall response rate decline (Lowe, Harzem, & Spencer, 1979) while number of responses (Hanson, Campbell, & Witoslawski, 1962) increases. Lowe, Davey, and Harzem (1974) found that running rate and postreinforcement pause length increased on an FI 60-s schedule as a function of the concentration of a condensed milk solution, while overall rate stayed constant or decreased. Azrin and Holz (1961) found that punishing each response on an FI schedule reduced response rate but did not affect the temporal pattern of responding. Additional manipulations shown to influence FI responding have included level of deprivation (Collier & Willis, 1961) and the effect of concurrent scheduling on FI performance (Catania, 1966).

Adult human FI performance differs markedly from that of nonhumans, typically consisting of either high- or low-rate responding. Figure 1, taken from Weiner (1969), shows human cumulative records in various FI manipulations. All conditions were conducted for 10 1-hr sessions, and a reinforcer was 100 points. Importantly, subjects were paid an hourly wage, irrespective of performance; points earned were *not* exchangeable for money. The data at the top show 6 subjects responding at very high rates in the FI 10-s condition, 1 subject (141) relatively high, and 2 subjects (111, 244) at very low rates. Cumulative records in the middle of the figure show FI 600-s exposure, resulting in five high-rate and four low-rate patterns. The bottom records, FI 10-s–cost, added the contingency that each response subtracted one point from the 100-point reinforcer. In this procedure, 2 humans emitted high-rate performance and 7 emitted low-rate performance, which was almost the opposite of the FI 10-s procedure without the cost contingency (top).

It has also been shown that human responding can be affected by requiring greater effort to respond (Azrin, 1958), the use of concurrent schedules (Poppen, 1972, 1982), experimenter instructions (Baron, Kaufman, & Stauber, 1969; Catania, Matthews, & Shimoff, 1982; Matthews, Shimoff, Catania, & Sagvolden, 1977), the use of a clock (Baron & Galizio, 1976), and noise (Azrin, 1958).

Additionally, reinforcement history has been shown to affect human performance. Weiner (1964), for example, first exposed subjects to either a fixed-ratio (FR) 40, requiring 40 responses for each reinforcer, or a differential-reinforcement-of-low-rates (DRL) 20-s schedule and then found high-rate FI performance in the former and low-rate performance in the latter group. He has also shown (Weiner, 1965) that subjects did not receive all of the available reinforcers on a variable-interval (VI) schedule after a DRL history because of their low rates of responding on the VI schedule.

Human subjects have emitted a scalloped pattern of responding in a few studies, but only with the addition of special contingencies. For example, Holland (1958) engaged subjects in a signal-detection task: On an FI schedule, in which a dial pointer was deflected when the interval timed out, the subject was required to press a button when this deflection occurred. The dial pointer was hidden from view, but subjects could press an observing key which gave access to its location. A scalloped pattern of observing responses developed. Engaging subjects verbally during a signal-detection task (Laties & Weiss, 1963) and increasing the force required to operate pushbuttons (Azrin, 1958) also produce scalloping. Note, however, that the scalloped pattern developed in experiments that were not comparable to nonhuman procedures; it is not necessary to overlay special contingencies on the FI schedule with nonhumans.

Differences in response patterns between nonhumans and humans (primarily regarding how difficult it is to show scalloping in humans) have been attributed to a number of possible reasons. Bentall and Lowe (1987) suggested that nonhumans are different from humans because verbal behavior plays the deciding role in controlling human behavior, and that this qualitatively distinguishes human from nonhuman behavior. By studying children of various ages (preverbal as well as verbal), Bentall, Lowe, and Beasty (1985) have shown that verbal children behave similarly to adults on FI schedules (showing low- or high-rate performance), whereas preverbal children show evidence of scalloping. On this basis, they concluded that verbal behavior plays a major role in the schedule performance of humans.

Taking this conclusion to task, Perone, Galizio, and Baron (1988) have suggested that comparing human and nonhuman performance is questionable for a number of reasons. For example, although conditions are basically standardized for nonhuman subjects (e.g., deprivation levels, operant equipment used), laboratory procedures vary widely in human research. Importantly, they also indicate that there are discrepancies in performance between *nonhuman* species (e.g., rats are more easily controlled by temporal contingencies than are pigeons) that have yet to be explained.

A major difference between most human and nonhuman experiments, and the focus of our experiments, is the degree of conditioning history. In comparing human and nonhuman schedule performance, the behavior of experimentally naive nonhumans is compared to the behavior of humans with extensive and varied extralaboratory history. There is evidence that schedule history can dramatically affect FI performance; as noted earlier, experimentally imposed DRL history produces low-rate FI performance in humans (Weiner, 1969). It is plausible that schedule history outside of the laboratory could have similar effects on performance in the laboratory. The failure to obtain scalloped response patterns with humans on FI schedules may be partly due to their extensive history outside of the laboratory (especially with button pressing), and it is equally plausible that nonhumans with schedule histories would not produce scalloped response patterns.

Although we have identified no nonhuman studies designed to address the present concern, a few studies have produced relevant data. Alleman and Zeiler (1974) presented pigeons with various sequences of the following schedules: fixed time (FT), response-independent delivery of food after a certain amount of time; fixed ratio (FR), requiring a set number of responses before reinforcement; and interresponse time (IRT) > *t*, requiring interresponse times greater than *t* s for reinforcement to occur. They found that prior FR exposure caused a scalloped pattern of responding to develop during subsequent FT exposure. Very clearly, then, history affected pigeon performance on a subsequent schedule.

The effects of schedule history on FI schedules were suggested in a pharmacological study by Urbain, Poling, Millam, and Thompson (1978) who exposed rats to 50 sessions of either FR 40 or IRT > 11-s histories. All rats were then presented with an FI 15-s schedule. The rats exposed to the FR-40 schedule emitted higher rates of responding under the subsequent FI contingency than did the rats exposed to the IRT > 11 s, and, after 93 sessions, their patterns of behavior remained distinct. These findings with rats were very similar to Weiner's (1964, 1969) findings with human subjects. It is interesting, as the authors point out, that after equating schedule histories, humans and rats will behave so similarly on FI schedules.

It appears, then, that conditioning history may play a major role in both nonhuman and human performance, and that prior history might be another variable to help account for apparent nonhuman–human FI discrepancies. This question was pursued further in the following experiment, which examined the effect of prior exposure to a variable-ratio (VR) schedule upon subsequent FI performance in rats. Our study utilized a VR 20 to ensure a history of high-rate responding, and an FI 30-s schedule was selected because it lends itself typically to clear evidence of scalloped response patterns in rats.

METHOD

Subjects

Eight experimentally naive adult male albino rats were housed individually and maintained at 80% of their free-feeding weights. Water was available continuously in their home cages.

Apparatus

Four Gerbrands (Model G7210) rat operant chambers were enclosed in sound-attenuating enclosures. The left lever was covered by a metal project box (7 cm wide by 13 cm long) rendering it inaccessible. The operable lever was located 10 cm above the chamber floor to the right of the food tray, below two stimulus lamps. Food pellets (45 mg) were delivered into a food tray centered on the back wall of the chamber, 2.5 cm above the grid floor. The chambers were illuminated by a houselight mounted on the ceiling.

Experimental events were controlled and recorded by an IBM PC®, connected to a Med Associates® interface. IRT recordings of numerical data, with 100 ms resolution, were stored on disc, and a Hewlett-Packard 7470-A® plotter generated synthetic cumulative records at a later time.

Procedure

Subjects were divided into two groups: the experimental group (R1–R4), which received the VR exposure, and the control group (R17–R20), which received the FI without a prior exposure to VR. After initial magazine and lever-press training, subjects received three 1-hr FR 1 sessions (with a limit of 100 reinforcers per session).

The experimental rats received the following schedules in this order: VR 20, FI 30 s, VR 20, FI 30 s. Exposure to each schedule lasted 30 sessions, except in the first FI exposure, which lasted 40 (for an explanation, see Discussion). The FI-only rats received FI 30 s for a total of 120 sessions.

The session length for VR schedules was 20 min and, for FI 30 s, 30 min. Sessions, conducted 7 days per week, were terminated either after the designated session length or 100 reinforcements, whichever came first.

RESULTS

Figure 2 shows cumulative records of the FI performance of the experimental rats during Sessions 5, 15, and 30 after the first VR 20 exposure, and Figure 3 shows records of performance after the second VR 20 exposure. Records were selected from the middle 10 intervals of these sessions to minimize the experimenter bias attendant to the common practice of selecting representative records. Following both VR exposures, 3 of 4 experimental rats (R1, R2, and R4) showed evidence of scalloping in less than 5% of total daily trials, with no scalloping seen typically on a daily basis during the first and second FI

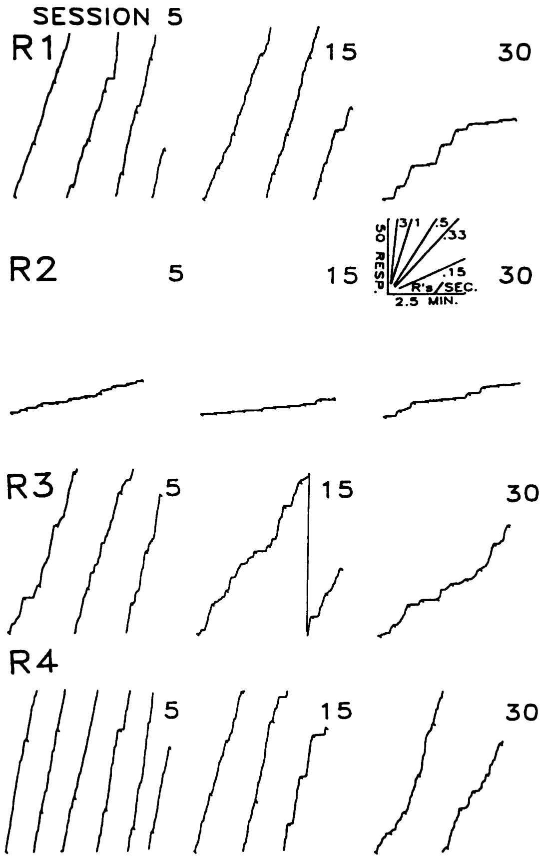

Fig. 2. Cumulative records of FI 30-s performance after a 30-session exposure on VR 20. Depicted here are the middle 10 intervals of Sessions 5, 15, and 30 for all 4 subjects in this condition.

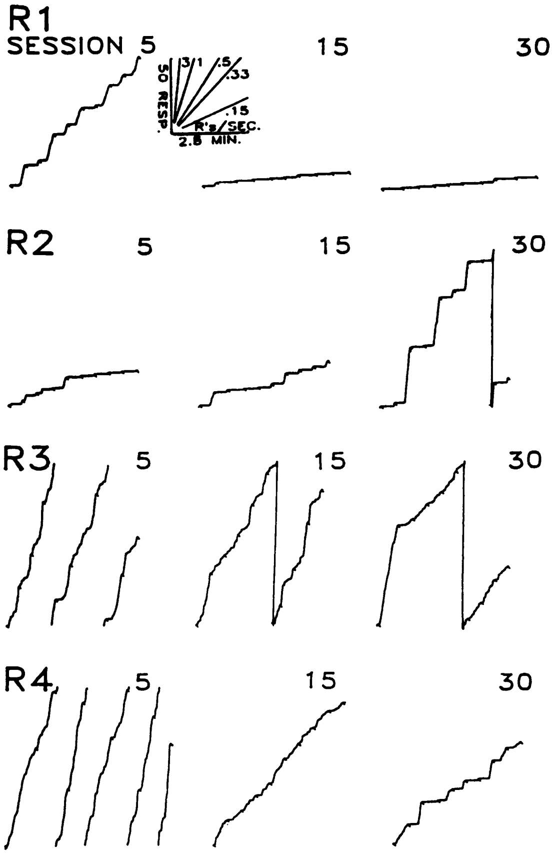

Fig. 3. Cumulative records of FI 30-s performance after the second VR 20 exposure. The middle 10 intervals of Sessions 5, 15, and 30 are shown.

exposures. The records presented here suggest the typical pattern progressions, with responding characterized by a mixture of high- and low-rate performance and some break–run patterns. R3 emitted high-rate patterns more than half of the time, and fewer than 20% of the trials showed scalloping (note that some scallops have been picked up in his records in both Figures 2 and 3).

Daily cumulative records for an entire session (interval by interval) were logged by two of the experimenters (due to space limitations, these records could not be presented here). This analysis revealed that the rats differed in their modal performances in the first exposure to FI 30 s. R1 and R4 emitted high rates for approximately two thirds (21 sessions) of the 30-session FI exposure. They then settled into lower rate and break–run patterns, and R4 occasionally emitted higher rates and paused erratically (as evidenced in Figure 2, Session 30). R2 emitted high rates only in the first two sessions, and his pattern (depicted in Figure 2) typifies his performance over the entire condition (i.e., very low rates). R3 produced the most variable cumulative records in this condition. He (as R1 and R2) also produced high-rate patterns for approximately the first 20 sessions and also showed erratic pausing (similar to R4's final data) half-way through this condition, but with evidence of *both* negative and positive acceleration (see Sessions 15 and 30, Figure 2). Overall, then, 3 of 4 subjects maintained high rates, giving way to lower rate break–run patterns through most of this first FI exposure, and 1 produced extremely low rates consistently. Only 1 rat (R3) showed clear evidence of scalloping, and that was quite infrequent.

Compared to the first FI exposure, daily cumulative records from the second exposure to the FI revealed shorter initial high-rate patterns for R1, R3, and R4. R1 settled into the low-rate pattern seen in Figure 3, Sessions 15 and 30, after only six sessions. R2 continued the pattern of very low-rate responding he had developed during the first FI exposure, and the break–run pattern of Session 30 (Figure 3) was not typical of his cumulative records. R3, in this second exposure, more quickly started the erratic pausing (after 10 sessions) but continued emitting high rates for approximately one third of the exposure (11 sessions) and settled into a lower rate break–run pattern.

Therefore, 3 subjects showed persistence of high rates lasting approximately two thirds of the first FI exposure but lasting only one third of the second FI exposure. These subjects' high rates always gave way to low-rate or low-rate break–run patterns. Aside form occasional negative and positive acceleration seen with R3, there was virtually no other evidence of scalloping in these performances.

Cumulative records for the subjects without VR history (R17, R18, R19, and R20) are presented in Figure 4 for Sessions 5, 15, and 30; 35, 45, and 60; 65, 75, and 90; and 95, 105, and 120. As with the rats exposed to VR schedules, the cumulative records for these rats include the middle 10 intervals only. Cumulative records were selected from session numbers comparable to those drawn for the VR rats, taking into account both the number of sessions of current FI exposure and total sessions of VR and FI exposure. For example, it could be argued that the first 30 sessions of FI exposure for the VR rats should be compared to the first 30 sessions of FI exposure of the FI-only rats. Alternatively, one might argue that the first 30 sessions of FI for the VR rats should be compared to Sessions 31 through 60 of the FI-only rats, because this would compare the groups at points at which they had comparable total schedule history.

Regardless of whether the first or the second block of 30 sessions of data from the FI-only rats is used for comparison to the VR rats, it is clear that R17, R18, and R20 produced scallops during both epochs, and R19 showed evidence of scalloping primarily during early sessions. As with the VR rats, entire-session daily records were logged interval by interval (space limitations preclude inclusion here). We considered a session to be primarily scalloped if at least 40% of the intervals were registered as scalloped in the log with no other pattern (high, low, or break–run) reaching that percentage. Primarily scalloped patterns eventually began to give way to break–run patterns in R17 after 60 sessions; to very low-rate patterns in R18 after 69 sessions; to very low-rate patterns in R19 after 10 sessions of scalloping; and to lower rate break–run patterns after 70 sessions in R20.

The rate of responding, calculated by dividing the total session responses by session length, and mean latency to the first response following each reinforcer are presented in Figure 5 for both groups. For the experimental subjects, this figure displays these measures during both VR and FI conditions, permitting examination of the relationships between measures of rate and latency during VR exposure and during subsequent FI exposures. It is clear that response rates and latencies were sensitive to schedule changes; when changed from VR to FI, rates fell rapidly while latencies increased to nearly the duration of the interval value by the end of the condition. Behavior during the FI exposures was not simply a function of behavior during the preceding VR period. Indeed, latencies increased and rates fell, by the end of 30 sessions of FI exposure, to levels comparable to the terminal levels of FI-only subjects. Few differences in rates and latencies were seen between the first and second FI exposures, except that transitions to terminal performance were quicker in the second exposure.

Quantitatively demonstrating the differential effects of history on the experimental and control groups has been a difficult task because, as the cumulative records show, VR history produced a variety of response patterns ranging from low- to high-rate performances, whereas most of the cumulative record patterns emitted by the control subjects were scallops. Presentation of traditional indices of responding such as response rate or latency, whether computed as means or medians, do not reflect fully the nature of the differences between the groups; these measures do not present the essentially bimodally high- and low-rate performances of subjects in the VR group. A variety of measures of FI responding have been developed (e.g., Fry, Kelleher, & Cook, 1960;

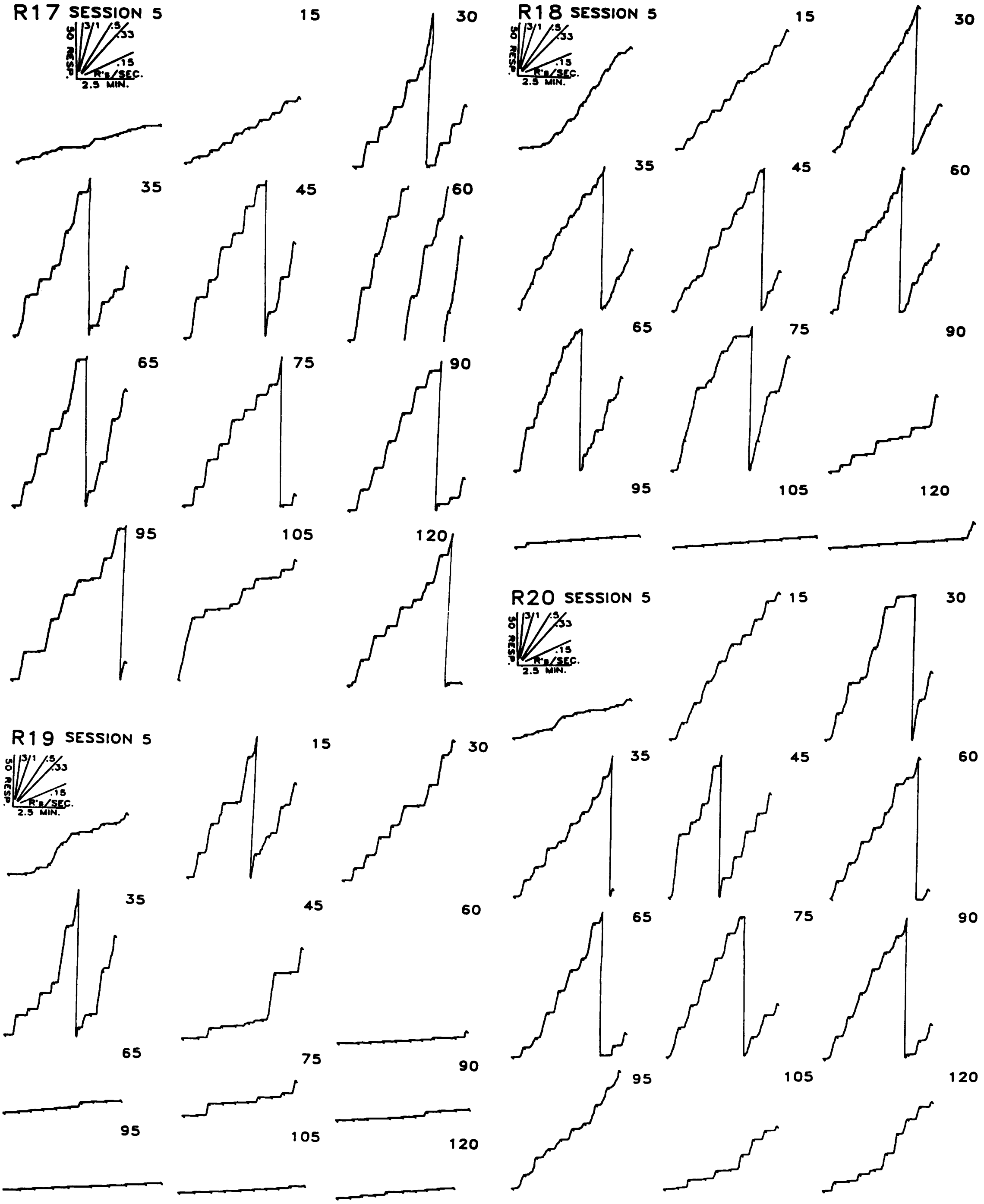

Fig. 4. Cumulative records of FI 30-s data on the control rats who were not exposed to a VR schedule. The sequence of presenting Sessions 5, 15, and 30 was extended through to Session 120. The middle 10 intervals of the indicated sessions are presented.

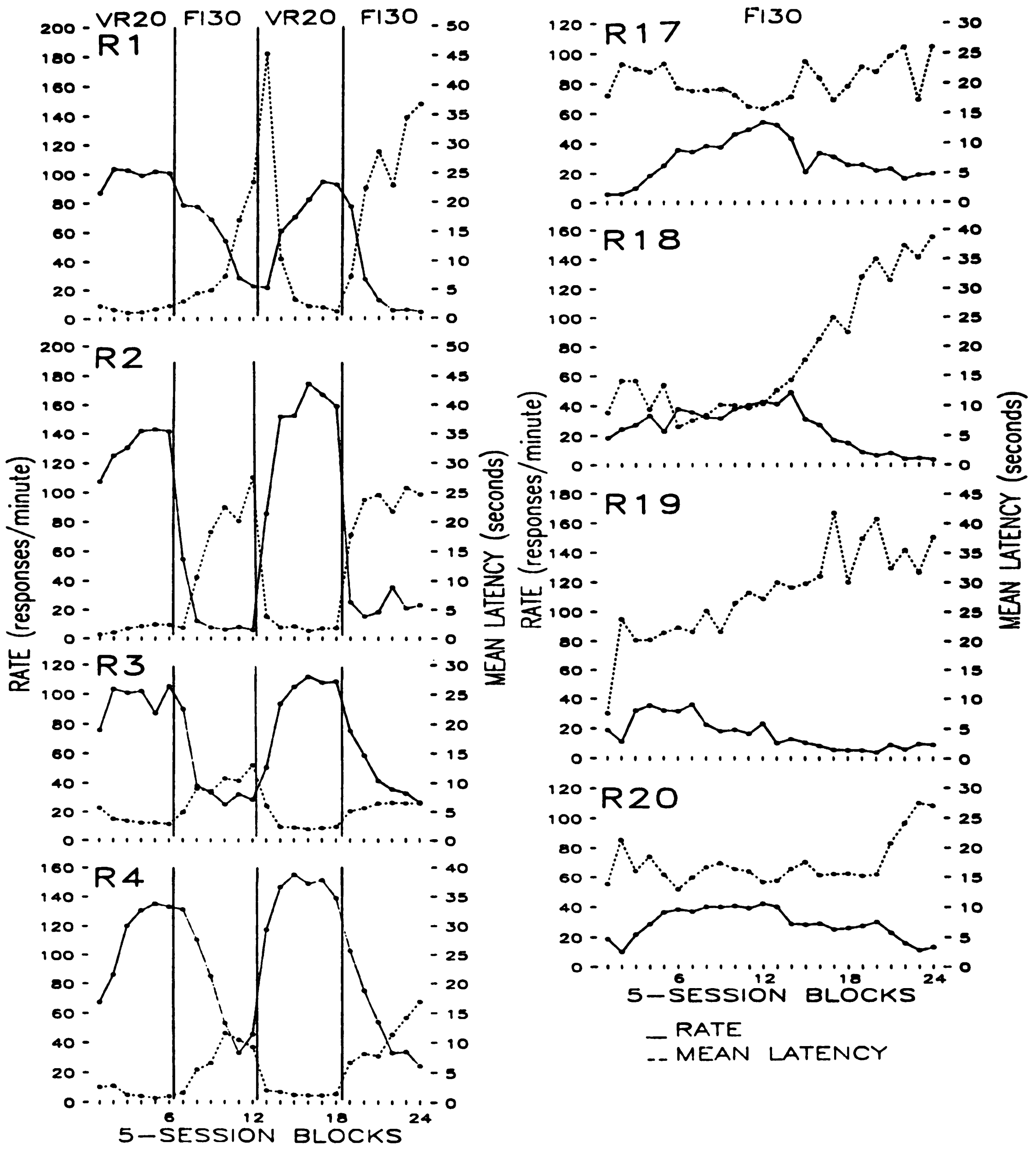

Fig. 5. Rate (total number of responses divided by session length) and mean latencies to the first response (in seconds) were computed in five-session blocks. The left side shows each condition for the experimental subjects, and the right shows control subjects' data. The abscissa is numbered 6, 12, 18, and 24 (the final blocks per condition of the experimental rats) to facilitate comparisons between the two groups of rats for comparable numbers of blocks of data.

Herrnstein & Morse, 1957). The Mathematical Index of Curvature (MIC) (Fry et al., 1960) was computed for every interreinforcer interval for every subject, and distribution of this statistic as well as measures of central tendency of this statistic were computed and examined but failed to reveal any systematic differences between subjects in the VR and control groups; hence, the data are not presented here.

The failure of the MIC to differentiate

among the groups probably reflects the failure of the VR group's data to satisfy the assumptions of the statistic. In particular, the MIC is inappropriate for interreinforcer intervals in which only a few responses have occurred (Fry et al., 1960). Furthermore, the MIC is primarily determined by the duration of postreinforcement pauses (Gentry et al., 1983). An example of the difficulty posed by this feature is that the measure is largely unable to distinguish between break–run and scallops with approximately equal postreinforcement pauses. Indeed, the MIC probably should never be used to differentiate among response patterns because a given pattern may produce a wide range of MIC values.

Differences in response patterns in the present data are more readily shown by relative frequency distributions of response rates, as shown in Figures 6 through 8. Figure 6 shows VR subjects' first FI exposure; Figure 7, the second FI exposure; and Figure 8, the FI-only subjects' data. These three figures depict Sessions 5, 15, and 30 for each subject (as was done with the cumulative records). These distributions show whether the predominant rate was low, high, or a mixture of both low and high. The response rates were calculated interval by interval, for individual sessions, by dividing the number of responses in each interval by the duration of the interval and assigning the quotient to bins. Each bin is 10 responses per minute in width. For example, two responses emitted in an interreinforcer interval of 40 s would be assigned to the first bin (0–10 s). The total number of interreinforcer intervals with response rates in each bin was then divided by the total number of interreinforcer intervals in the session to produce the relative distribution of response rates. Unlike the abscissa of plots of IRT distributions, increasing rates of responding on the present figures are plotted from left to right.

Interpretation of data presented in this form is especially unambiguous when response rates are predominantly low (0–10 responses per minute). For example, it can be seen that the cumulative record for R1 on Day 30 (Figure 3) and the corresponding rate distribution (Figure 7) both show very low-rate responding. In contrast, the cumulative record for R18 on Day 30 (Figure 4) shows scalloping, which is reflected in the corresponding rate distribution (Figure 8) as response rates clustering primarily in the range of 30 to 50 responses per minute, with a mode of 40. This is not to suggest that response rates clustering in the 30 to 50 range necessarily indicate scalloping, but these distributions do conveniently reflect differences across rats and across time within individual rats.

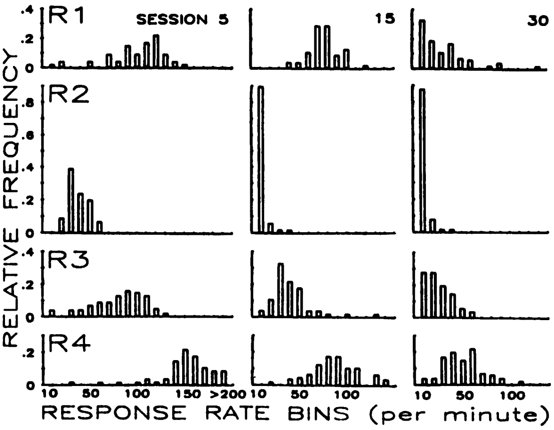

Fig. 6. The relative frequency of rates in bins of 10 responses per minute for the experimental rats. These are entire-session data for first FI-exposure Sessions 5, 15, and 30.

Specifically, Session 5, for VR subjects' first and second FI exposures (Figures 6 and 7), shows a relatively wide distribution of rates, within and between rats, with a substantial percentage of intervals having rates exceeding 100 responses per minute. Session 5 for the control subjects (Figure 8) shows a less variable response rate, with lower rate patterns (typically below 40 responses per minute) predominating.

Session 15 response rates, relative to those of Session 5, show decreased rates during the experimental rats' first FI exposure (Figure 6) and even greater decline during their second exposure (Figure 7), whereas control rats showed slightly increased rates with somewhat greater variability (Figure 8). By Session 30, VR rats were consistently emitting their lowest rates, whereas the control rats showed considerable inter- and intrasubject variability, with modes of 60 (R17 and R20), 40 (R18), and 10 (R19) responses per minute.

A comparison was also made between the second-exposure data of the VR subjects and the "second exposure" of the controls. This was done in two ways, by comparing the ex-

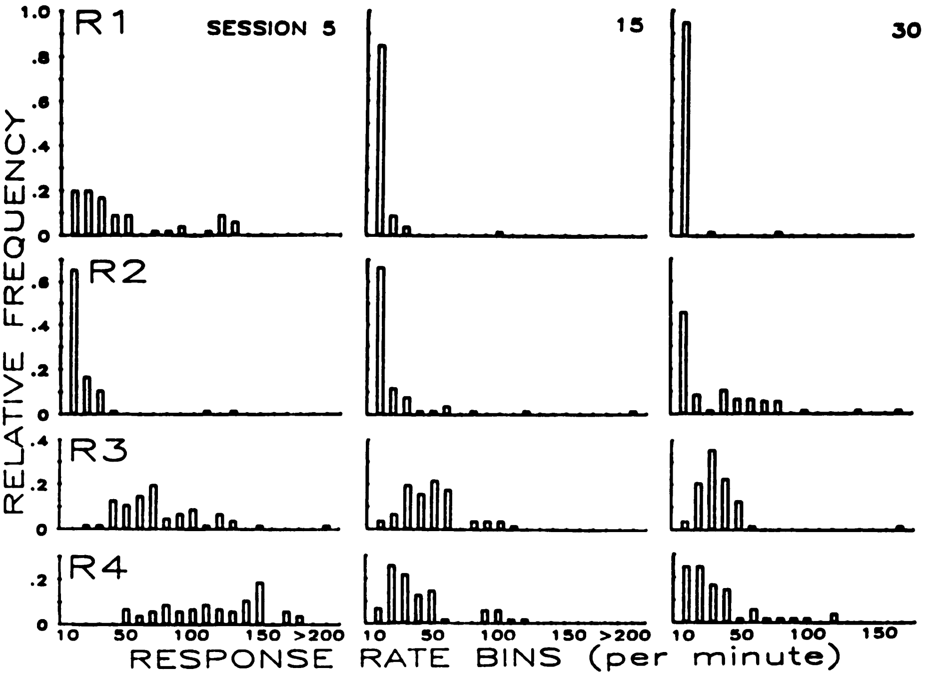

Fig. 7. The relative frequency of rates in bins of 10 responses per minute for the experimental rats' second FI exposure. Entire-session data are presented for Sessions 5, 15, and 30.

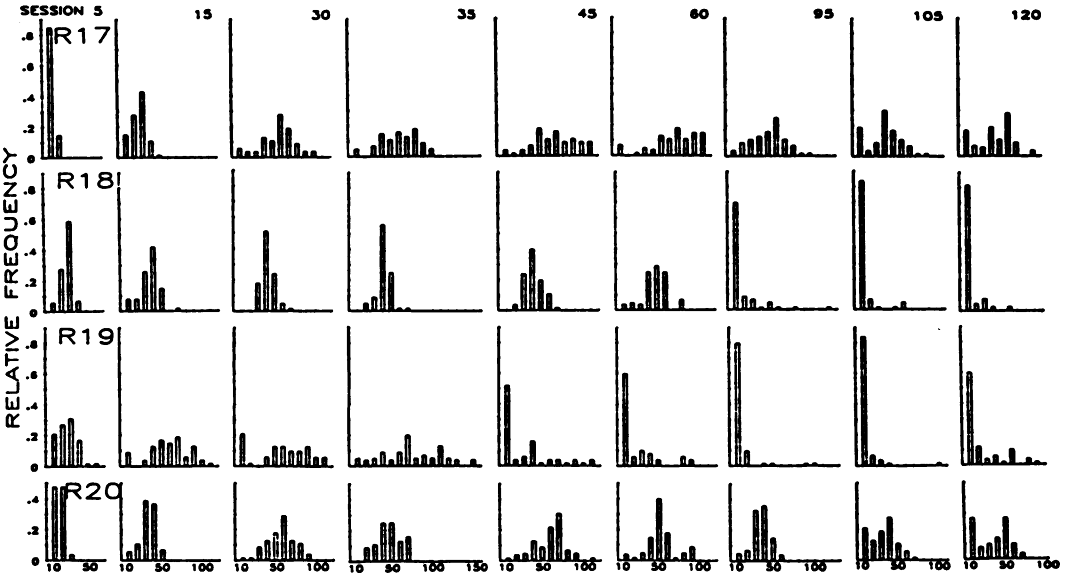

Fig. 8. These data were taken from the control subjects over a sequence of 5, 15, and 30 sessions, extended to Session 120. Depicted is the relative frequency of rates in bins of 10 responses per minute.

perimental rats' (Figure 7) performance to, first, Control Sessions 35, 45, and 60 and, second, Control Sessions 95, 105, and 120; these are depicted in Figure 8. The first comparison equates the two groups in terms of the actual (sequential) number of sessions on the FI; for example, Session 35 is the 35th session of FI exposure for both experimental and control rats. However, the experimental rats received a 30-session VR between the first and second FI exposures, so the second comparison was made (of controls' 95, 105, and 120 sessions) to account for the control rats' additional 30 sessions of FI received while the experimental rats were receiving the VR.

In the first comparison, the experimental rats (Figure 7), by Session 30, settled into a lower rate and less variable distribution (except for R2, who showed increased variability). Most of the rates at that session were at or below 30 responses per minute. In contrast, controls (Figure 8) continued to show considerable variability among rats and, overall, much higher rates (except R19). In the second comparison, viewing the final 30 sessions of the control subjects (Figure 8), there are many more instances of very low-rate responding (many at 10 responses per minute) and less dispersion.

These rate distributions support the effects seen in the cumulative records; that is, the rates among the VR rats were highest immediately following VR exposure with the proportion of low rates increasing steadily as a function of FI exposure. Further, the speed of transition to low rates was faster following the second VR exposure. In contrast, the rate distribution of the FI rats began with low rates predominating, which then turned to intermediate rates corresponding to the scallops seen in the cumulative records from the same session. As with the VR rats, terminal performance was characterized by declining response rates.

DISCUSSION

It is clear that the experimental rats behaved very differently than the control subjects did. The latter rats progressed predictably through the standard FI behavioral patterns, showing scallops, then low rates, some with break-runs. The experimental rats, on the other hand, emitted primarily high- with some low-rate patterns; this is more characteristic of adult human patterning (for a comparison, see Figure 1). There are also some similarities between the experimental and control rats' terminal performance patterns, indicating that a history of VR schedule exposure may expedite terminal FI performance.

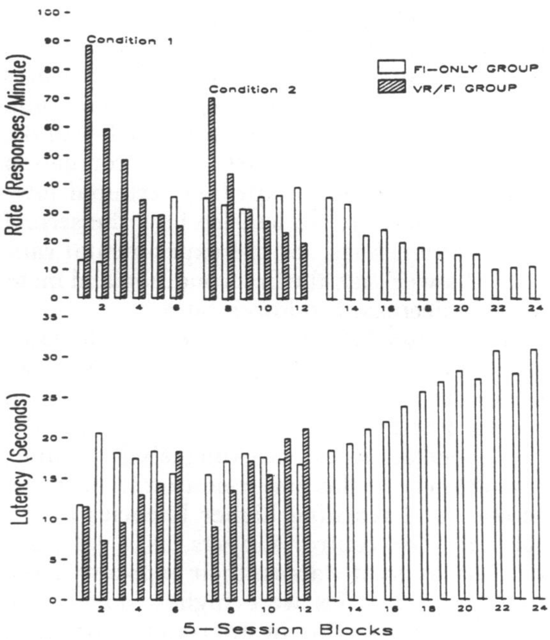

Fig. 9. Group means of rate and latency for both the control and experimental subjects. Data were averaged across five-session blocks for both first and second FI exposures, which lasted 30 sessions each. Control rats, who continued to receive the FI contingency, were analyzed throughout their 120-session exposure. It is suggested that the experimental rats' exposure to the VR schedule hastens development of FI performance into its terminal pattern of low rate and long latency.

Figure 9 shows mean rate and latency measures averaged across the 4 subjects in each group over five-session blocks. The control group is represented by the open bars and the experimental rats by the hatched bars. The top of the graph shows the control group starting with very low rates of responding (10–20 responses per minute) and then increasing gradually to roughly 40 responses per minute by the end of the second 30-session FI condition (Block 12). In contrast, the experimental rats started at approximately 90 responses per minute and, by the end of the first condition, had dropped below (with a mean rate of 20 responses per minute) the rate of the control group. We extended the group means for the control group throughout the 120-session exposure to show that, eventually, stable and very low rates developed (10–20 responses per minute). Note that the experimental group produced these lower rates much earlier in the FI exposure, thus supporting our contention that the VR history expedites terminal low-rate FI behavior. Notice also how the second FI condition rates, for the experimental rats, started lower than the first condition and more quickly decreased to lower rates.

The bottom half of this figure was calculated similarly to the latency measure, averaged across the subjects in each group in five-session blocks. Further evidence is seen here that the experimental rats' latencies increased over time, more slowly in the first condition than in the second (and reaching higher latencies in the second). The control subjects, as a rule, did not vary as greatly across their exposure. Note that their latencies were highest during the final blocks (starting at approximately Block 18 and on), which were comparable to the experimental rats' latencies by Block 12.

Thus, the rates and latencies of the experimental rats changed more quickly in the second FI exposure than the first and became typical of terminal FI performance more quickly than the rates and latencies of control rats. Further research is clearly required, but perhaps human low-rate performance on FI schedules could also be viewed as a manifestation of heightened schedule sensitivity resulting from prior extralaboratory reinforcement histories.

In another vein, we find it ironic that scalloping is taken typically as the benchmark for assessing sensitivity to interval contingencies, because, as others have shown (e.g., Dews, 1978), the break–run pattern can be as typical as the scallop and, over time, the break–run is the predominant pattern (Cumming & Schoenfeld, 1958). We found that an extended FI exposure with rats results in a break–run and/or very low-rate terminal performance.

Note that, in the Procedure section, we stated that the VR-history rats' first FI 30-s exposure actually lasted 40 days. At the time, we were exploring the possibility that the scallop might return if we presented more sessions of FI 30 s, because latencies were increasing and rates decreasing at the 30-session mark. This did not happen—data from sessions beyond that point were similar to the preceding data.

We hoped to show that it is not wise to compare a human with a complex history of reinforcement to a naive laboratory nonhuman. We chose a VR schedule because it produces high rates that might be representative of what humans are subjected to in this culture; standing at an elevator that is not arriving quickly and observing humans button pressing is enough to suggest the utility of a program of research with a variable schedule that produces high rates of responding.

Although our results may not show classic human-like FI responding, they do not show classic nonhuman-like responding either. We believe our results are more like the human patterns overall and suggest at the very least that conditioning history may be an important variable in an organism's response patterns. Further, it may be premature to compare any human data to nonhuman data because procedural differences are so great, and humans are typically not exposed to experimental contingencies for as long as nonhuman subjects. Weiner's (1969) data were selected (Figure 1) as the basis for comparison because humans were exposed for 10 1-hr sessions, a reasonable amount of time. However, it is also true that points were used as reinforcers (rather than a primary reinforcer such as food), and subjects were paid a fixed sum for participation, irrespective of performance.

In addition to showing the effects of conditioning history on subsequent FI performance, we also hope that our data suggest the utility of assuming interspecies continuity. We cautiously advise invoking uniquely human processes to explain discrepancies between the performance of humans and nonhumans only after thoroughly exhausting traditional approaches and finding those wanting.

REFERENCES

Alleman, H. D., & Zeiler, M. D. (1974). Patterning with fixed-time schedules of response-independent reinforcement. *Journal of the Experimental Analysis of Behavior*, **22**, 135–141.

Azrin, N. H. (1958). Some effects of noise on human behavior. *Journal of the Experimental Analysis of Behavior*, **1**, 183–200.

Azrin, N. H., & Holz, W. C. (1961). Punishment during fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior*, **4**, 343–347.

Baron, A., & Galizio, M. (1976). Clock control of human performance on avoidance and fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, **26**, 165–180.

Baron, A., Kaufman, A., & Stauber, K. A. (1969). Effects of instructions and reinforcement-feedback on human operant behavior maintained by fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior,* **12,** 701–712.

Bentall, R. P., & Lowe, C. F. (1987). The role of verbal behavior in human learning: III. Instructional effects in children. *Journal of the Experimental Analysis of Behavior,* **47,** 177–190.

Bentall, R. P., Lowe, C. F., & Beasty, A. (1985). The role of verbal behavior in human learning: II. Developmental differences. *Journal of the Experimental Analysis of Behavior,* **43,** 165–181.

Catania, A. C. (1966). Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 213–270). New York: Appleton-Century-Crofts.

Catania, A. C., Matthews, B. A., & Shimoff, E. (1982). Instructed versus shaped human verbal behavior: Interactions with nonverbal responding. *Journal of the Experimental Analysis of Behavior,* **38,** 233–248.

Collier, G., & Willis, F. N. (1961). Deprivation and reinforcement. *Journal of Experimental Psychology,* **62,** 377–384.

Cumming, W. W., & Schoenfeld, W. N. (1958). Behavior under extended exposure to a high-value fixed interval reinforcement schedule. *Journal of the Experimental Analysis of Behavior,* **1,** 245–263.

Dews, P. B. (1978). Studies on responding under fixed-interval schedules of reinforcement: II. The scalloped pattern of the cumulative record. *Journal of the Experimental Analysis of Behavior,* **29,** 67–75.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Fry, W., Kelleher, R. T., & Cook, L. (1960). A mathematical index of performance on fixed-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior,* **3,** 193–199.

Gentry, G. D., Weiss, B., & Laties, V. G. (1983). The microanalysis of fixed-interval responding. *Journal of the Experimental Analysis of Behavior,* **39,** 327–343.

Hanson, H. M., Campbell, E. H., & Witoslawski, J. J. (1962). FI length and performance on an FI FR chain schedule of reinforcement. *Journal of the Experimental Analysis of Behavior,* **5,** 331–333.

Herrnstein, R. J., & Morse, W. H. (1957). Effects of pentobarbital on intermittently reinforced behavior. *Science,* **125,** 929–931.

Holland, J. G. (1958). Human vigilance. *Science,* **128,** 61–67.

Laties, V. G., & Weiss, B. (1963). Effects of a concurrent task on fixed-interval responding in humans. *Journal of the Experimental Analysis of Behavior,* **6,** 431–436.

Lowe, C. F. (1979). Determinants of human operant behaviour. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol 1. Reinforcement and the organization of behaviour* (pp. 159–192). Chichester, England: Wiley.

Lowe, C. F., Beasty, A., & Bentall, R. P. (1983). The role of verbal behavior in human learning: Infant performance on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior,* **39,** 157–164.

Lowe, C. F., Davey, G. C. L., & Harzem, P. (1974). Effects of reinforcement magnitude on interval and ratio schedules. *Journal of the Experimental Analysis of Behavior,* **22,** 553–560.

Lowe, C. F., Harzem, P., & Spencer, P. T. (1979). Temporal control of behavior and the power law. *Journal of the Experimental Analysis of Behavior,* **31,** 333–343.

Matthews, B. A., Shimoff, E., Catania, A. C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. *Journal of the Experimental Analysis of Behavior,* **27,** 453–467.

Perone, M., Galizio, M., & Baron, A. (1988). The relevance of animal-based principles in the laboratory study of human operant conditioning. In G. Davey & C. Cullen (Eds.), *Human operant conditioning and behavior modification* (pp. 59-85). Chichester, England: Wiley.

Poppen, R. (1972). Effects of concurrent schedules on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior,* **18,** 119–127.

Poppen, R. (1982). Human fixed-interval performance with concurrently programmed schedules: A parametric analysis. *Journal of the Experimental Analysis of Behavior,* **37,** 251–266.

Schneider, B. A. (1969). A two-state analysis of fixed-interval responding in the pigeon. *Journal of the Experimental Analysis of Behavior,* **12,** 677–687.

Urbain, C., Poling, A., Millam, J., & Thompson, T. (1978). *d*-Amphetamine and fixed-interval performance: Effects of operant history. *Journal of the Experimental Analysis of Behavior,* **29,** 385–392.

Weiner, H. (1964). Conditioning history and human fixed-interval performance. *Journal of the Experimental Analysis of Behavior,* **7,** 383–385.

Weiner, H. (1965). Conditioning history and maladaptive human operant behavior. *Psychological Reports,* **17,** 935–942.

Weiner, H. (1969). Controlling human fixed-interval performance. *Journal of the Experimental Analysis of Behavior,* **12,** 349–373.

Received August 5, 1988
Final acceptance April 28, 1989