Fixed-Interval and Fixed-Ratio Reinforcement Schedules With Human Subjects

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Operant laboratory studies were conducted as part of the regular activities of a psychiatric research ward. This report includes only some early data obtained from the ward staff, not the patients. A multiple schedule having alternating fixed-ratio and fixed-interval components permitted observations of acquisition and maintenance of behavior at low schedule values, transition to and final performance at greater schedule values, and behavioral changes after a limited-hold contingency was added to the fixed-interval. Prior to the added limited-hold, subjects used watches to time the interval, and usually responded only once before obtaining each fixed-interval reinforcement. Short limited-hold values eliminated clock watching and increased fixed-interval responding. Subjects communicated freely with each other, and it was clear that their performances were controlled both by the contingencies and by instructions. Just as clearly, the instructions themselves were controlled by the contingencies. It was concluded that the kinds of verbal control that were responsible for "nonstandard" fixed-interval performances did not require the postulation of any new behavioral principles.

Several years ago we conducted operant conditioning experiments on a research psychiatry ward of the Walter Reed Army Medical Center. Data deemed at that time not sufficiently new to warrant publication have now gained significance in relation to recent discussions of differences between human and nonhuman performance on reinforcement schedules, particularly on the fixed-interval schedule (for summaries and some recent data, see Lowe, 1983; Bentall, Lowe, & Beasty, 1985; and Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986). We report here some initial studies that simply established a baseline of operant behavior under the control of a multiple fixed-ratio, fixed-interval reinforcement schedule.

Full descriptions of the ward and the overall psychiatric research program have been

reported elsewhere (Artiss, 1959, 1962). Because the ward's therapeutic rationale entailed attempts to build a general atmosphere of group interaction and meaningful communication between staff and psychotic patients, many conventional distinctions between technicians and patients were removed. Everyone on the ward, whether patient or staff member, could participate in the operant experiments. The same rules applied equally to both groups, the experimental procedures had to be the same for all, there could be no hint of favoritism or any other kind of bias, and all participation was voluntary. Although these conditions imposed obvious restrictions on the kinds of operant investigations we could undertake, inclusion of the laboratory experience in the normal, everyday ward routine provided a unique opportunity to observe how experimentally established contingencies and subject-derived rules interacted in the governance of behavior. Because staff and patients did not differ with respect to these interactions, we shall report here only on the staff's behavior.

METHOD

Subjects

The staff consisted of the ward psychiatrist, one or two nurses, and 12 to 14 neuro-

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psychiatric technicians (corpsmen). A total of 17 staff members participated. The technicians worked in three daily shifts. One or two social workers, one or two secretaries, and the first author participated in varying degree with the patients in ward and ancillary research activities. Except for the nurses and secretaries, all were men. Educational levels differed widely, ranging from a high school education to advanced professional degrees.

Apparatus

Figure 1 shows a sketch of the experimental chamber. It was located near the corner of the ward's main dormitory room. The booth had no door. It contained a cushioned seat, a shelf, a ceiling light for general illumination and for indicating session duration, a panel that held two stimulus displays and response mechanisms, and a tray that received the reinforcers. Stimuli were colored 7-watt lights visible through frosted plastic windows. Below each window was a response plunger, the knob-pull type developed by Lindsley (1960). The subject could pull the plunger a distance of approximately 6.5 mm (1/4 in). The present studies used only the righthand plunger and the stimulus window above it.

The booth remained available to the subjects seven days a week at any hour. Programming and data-recording equipment were located in a room behind the booth. A token dispenser, mounted on the back of the booth, was accessible to the experimenter from this room. The specially-designed, six-stack dispenser could deliver up to 1200 tokens without reloading.

Print-out counters and Gerbrands cumulative recorders registered the data. All programming counters, timers, switching devices, and recording equipment reset to their "start" condition when a session ended or the next session began.

Reinforcers

The reinforcers were exchangeable tokens, poker chips engraved with an eagle. The engraving discouraged counterfeiting and mimicked official exchange. Subjects could trade their tokens at a "store" on the ward. The experimenter opened the store daily, except on weekends and holidays. Available in the store were many of the supplies usually found in a military Post Exchange or hospital store. The items included candy, cigarettes, pipes, magazines, books, art prints, toilet articles, stationery and writing supplies, gift items such as perfume and jewelry, and many more. Subjects also could exchange their tokens for trading stamps, or for credit if they wanted neither store items nor stamps, or they could accumulate tokens. A subject who saved enough stamps could obtain any of the items shown in the gift catalogue, copies of which were distributed about the ward. The pay scale varied with changes in the experimental conditions, but averaged approximately \$3.00 per hour. This permitted what was at that time a substantial increment in take-home pay.

Procedure

Operating schedule. Every subject could use the booth once a day, at any time that did not conflict with ward routine. A session lasted until a maximum time had elapsed, or until the subject obtained a maximum number of

Fig. 1. A sketch of the experimental apparatus.

tokens, or until the subject left the booth, whichever occurred first. Both maximum time and pay varied among the different phases, but the time limit was usually one-half hour. The ceiling light came on at the start of the session and went off when the session ended.

A subject who wanted to use the booth had to ask one of the key-bearing staff to turn on the apparatus. The ward nurse and each technician had a key that unlocked a compartment on the outside wall of the booth. This compartment contained a starting-button, a card on which the subject's name and the date and time of the session were recorded, a pen, and a calendar clock. The staff member recorded the identifying information and pressed the button that would start the session if the subject was seated in the booth. The subject's weight depressed the hinged floor of the booth against spring tension and closed a switch that permitted the apparatus to function. When the subject left the booth, the springs raised the floor and opened the switch. This event ended the session if the token counter or session timer had not already done so. The staff made only infrequent errors in recording information and identifying subjects, and these few were easily noted and corrected by several means of cross-checking.

Phase 1: Low value multiple schedules of reinforcement. Phase 1 examined the subjects' performance on a multiple fixed-ratio 10 fixed-interval 30 s schedule. When a red light was on behind the stimulus window, the reinforcement schedule was fixed-ratio; the subject obtained a token every tenth time he or she pulled the plunger. When a green light illuminated the window, the schedule was fixed-interval; the subject obtained a token the first time he or she pulled the plunger after the green light had been on for 30 seconds. Each time the subject received a token the color of the light changed, along with its associated reinforcement schedule. The fixed-ratio and fixed-interval schedules therefore alternated with each reinforcement. A subject could obtain no more than 25 tokens per session, and the maximum session duration was 30 minutes. A session might begin with either the fixed-ratio or the fixed-interval schedule.

Phase 2: Greater schedule values. After most subjects had developed stable performances, the schedule values were increased. The procedure was identical to Phase 1, except that the fixed-ratio was increased to 50 responses per token, and the fixed-interval to 60 seconds. Also, the number of tokens subjects could obtain per session was increased from 25 to 30.

Phase 3: Fixed-interval with limited-hold. The basic procedure and initial schedule values remained the same as in Phase 2. The token value was doubled at the start of Phase 3. The principal change was the addition of an upper limit to the fixed-interval. This "limited-hold" (Ferster & Skinner, 1957), restricted the amount of time a token remained available to the subject after the fixed-interval ended. The subject could obtain a token by pulling the plunger after the fixed-interval ended and before the limited-hold period ended. If a subject did not respond during the limited-hold time period, the stimulus light changed to red for the ratio schedule, and the subject missed that opportunity to obtain a token. The maximum number of reinforcements—still 30—did not change as a result of the missed opportunity. In a 10-week period, the duration of the limited-hold was progressively decreased through the following values: 5.0, 3.0, 2.0, 1.0, 0.75, and 0.5 s. While the 1.0 s value was in effect, the fixed-interval was increased from 60 to 63 s. Ultimately, subjects had to pull the plunger within 0.5 s after the end of a 63 s interval; if they did not, the schedule changed and they missed a reinforcement opportunity. A final condition examined the removal of the limited-hold.

Instructions to the subjects. A notice posted on the booth instructed the subjects as follows:

This booth is a token-machine. It is used for one of many studies on the behavior of people. Anyone here on this ward may join in the study and will be paid tokens for doing so.

The tokens can be exchanged for Top Value stamps or for prizes kept by me on the ward. The hours each week for exchanging tokens will be posted. Top Value Gift Catalogues will be left on the ward. Arrangements to get the Top

Value gift prizes will be made by the staff. The value of the tokens will be posted.

To use the machine you must sit inside the booth and have the nurse or a technician start it for you. Pulling the lever will get tokens—sometimes. You may stop when you want. The machine will turn itself off when you get out, or when the time or pay for that day has been used up.

The results of this study will be confidential and no names will be used. For now, the results cannot be told to anyone. Later on your results will be discussed with you if you are interested.

Additional notices advised subjects about the token value, the maximum pay and time, and the details and schedule of the store operation. In the outside compartment, instructions outlined the procedures for turning the apparatus on and for regulating the use of the booth. Subjects received no other instructions from the experimenters, but communication among subjects was not limited. After the introduction of new experimental procedures, it was usual for several patients and staff members to sit outside the booth observing and prompting the first few subjects, even timing the token deliveries with a stop watch and keeping notes. It had to be assumed that all subjects had access to and received any information possessed by any subject.

RESULTS

Phase 1: Multiple Fixed-Ratio 10 Fixed-Interval 30 s, First Session

Figure 2 shows the complete cumulative response record for every subject's first session. Where the pen reset to the baseline, the records were cut and spaced closely together for compact presentation. The session number follows each record. (Failure of the recorder pen lost most of Subject 119's and all of Subject 109's first-session data.) The longer times or the greater number of responses between alternate reinforcements typically indicate interval segments; when the diagonal marks are closely spaced, the second mark of the pair is a ratio reinforcement.

The records are arranged in the order in

which subjects first used the booth. Three patients had preceded Subject 107, the first staff member. The subjects had probably developed an accurate verbal description of the schedule at least by the time Subject 103 entered the booth on the first day. He was the first to pause consistently during the interval. Beginning with Subject 119, the first-session performances occurred after the first day of operation, and no one entered the booth without having been "clued in." Subjects continued to differ from each other, principally during the fixed-interval schedule. The effect of the shared schedule information was neither clear-cut or consistent.

All subjects' fixed-ratio performances were characterized from the outset by high response rates and no pause after the preceding reinforcement, but there were three general types of fixed-interval behavior. In one, the subjects pulled the plunger at a relatively high rate and did not pause after receiving a token on the ratio schedule (e.g., Subject 107). A second type of fixed-interval performance was characterized by a substantial pause after a ratio reinforcement and then a rapid burst of responses to terminate the interval (e.g., Subject 111). The third mode of responding in the fixed-interval was similar to the second, but the subject paused long enough for the first response to produce a token (e.g., Subject 103 late in the session).

Phase 1: Final Performance

Although some subjects settled into their final fixed-interval pattern during their first session, others, even with the shared information, required continued exposure to the reinforcement contingencies, to the social contingencies, or both, before their behavior of pulling the plunger came under schedule control. The left-hand record for each subject in Figure 3 shows the final performance in Phase 1. Except for some "checking out" in the first interval of the session, the final records (with the exception of Subject 114) became remarkably similar, most of the differences showing up as slight variations in fixed-interval pause length.

When their behavior on the multiple schedule stabilized, most subjects' fixed-ratio performances were characterized by high response rates without breaks. Most also paused longer than 30 s in the fixed-interval; after the pause, their first response

Fig. 2. First-session records of subjects on the multiple schedule: fixed-ratio 10 responses and fixed-interval 30 s. The records are in their order of occurrence, starting with Subject 107. Session numbers follow each record. Most of Subject 119's and all of Subject 109's first-session records were lost. The diagonal marks indicate reinforcements.

obtained the reinforcement and initiated the rapid fixed-ratio response rate. As a consequence, they usually pulled the plunger only once for each token on the fixed-interval schedule. When subjects did respond more frequently, they usually began abruptly late in the interval. In those instances, the response rate was constant and appeared to be equal to the fixed-ratio rate. Subjects sometimes pulled the plunger a few times at the start of the interval, showing "run-

throughs" after the fixed-ratio reinforcement. By this time, the subjects were regularly using watches to time the fixed-interval. This is probably why they generally pulled the plunger so efficiently.

Phase 2: Multiple Fixed-Ratio 50 Fixed-Interval 60 s, Transition and Final Performance

The right-hand record for each subject in Figure 3 shows the initial session of Phase 2, when the schedule values were

Fig. 3. All subjects' records of the last session on multiple fixed-ratio 10 responses and fixed-interval 30 s, and the first session on multiple fixed-ratio 50 responses and fixed-interval 60 s. The first-session records are in the order of their occurrence.

Fig. 4. The final-session records of subjects on the multiple schedule before and after the limited-hold. All staff members are included who performed on both the earlier schedule and on the shortest limited-hold condition. A session number follows the first record, and the 0.5 s limited-hold value follows the second record of each pair. Arrows mark missed reinforcement opportunities. In the limited-hold records, schedule changes are shown by maintained oblique upward or downward displacements of the pen, replacing the oblique marks in the earlier records.

increased. The first-session records of Phase 2 are presented in the order in which they occurred, from left to right, starting at the upper left. (Through a programming error, the first 4 subjects to experience the new schedule values received only 20 tokens.) By the end of Subject 119's session, the group had "solved" the multiple schedule: "One minute on the green—50 pulls on the red." Nevertheless, most of the succeeding subjects still were disrupted in their fixed-interval performance, particularly early in the sessions. In contrast to the disrupted fixed-interval performance, transition to stable fixed-ratio behavior occurred rapidly, with only Subjects 115 and 116 continuing to show pauses and lower rates in fixed-ratio periods up to the end of the session.

After their first session of increased schedule values, most subjects showed little or no extra fixed-interval responding, but their performances did require from 2 to 8 sessions to stabilize. The left-hand record for each subject in Figure 4 shows the final session (with its number) of Phase 2. Generally, subjects paused for the entire interval and produced the reinforcement with their first response. They then completed the ratio at a high rate and again paused during the next interval, and so on. A step-like curve resulted. If they did pull the plunger before an interval ended, they continued to respond until reinforced. In these instances, a high rate with an abrupt onset was most common, as in Phase 1, but rates lower than those of the fixed-ratio periods began to appear. The two failures to pause in Subject 107's last record were rare, but they illustrate the occasional departures from precise schedule control.

Phase 3: A Limited-Hold Contingency Added to the Fixed-Interval

The new procedure produced marked behavioral changes over the 10-week period. Figure 4 compares the final sessions before (Phase 2) and after (Phase 3) the addition of the limited-hold. A session number is at the end of the first record of the pair for each subject who worked on both procedures, and the 0.5 s limited-hold value is at the end of the second record. The limited-hold condition consistently increased the amount of fixed-interval responding.

Subjects took longer than in Phases 1 and

2 to arrive at an accurate description of the procedure, but it soon became current that "you can't wait too long." One subject later improved this rough conception, reporting, "If you don't pull the handle during a brief moment after the time is up, it switches to red and you don't get a chip."

The procedural changes in Phase 3 made clock watching more difficult. Few subjects continued to use a watch; most stopped regular clock watching, and many stopped entirely. One reported that he missed more often when he used a watch because he "called it too close."

Although a few subjects nearly attained their final performances as early as the first or second limited-hold value, changes in the fixed-interval behavior tended to be progressive and to occur gradually. Subject 107 (Figure 5) shows the more common progressive effect. First, his pauses shortened and he often responded at low rates. A fixed-interval rate more moderate than the fixed-ratio rate became consistent by the end of the 1.5 s condition. With further shortening of the limited-hold, his pauses remained relatively constant but his rate increased, although typically still not equalling his response rate in the fixed-ratio segments. Subject 107 also illustrates the general lack of gradual acceleration in the fixed-interval behavior. The terminal rate began abruptly and was maintained till the end of the interval.

Subject 107's behavior changed distinctly in the next fixed-interval period that followed each missed reinforcement opportunity. The pauses were shorter or the response output was greater, or both, than in most intervals. Several other subjects showed a similar immediate and local effect of the misses. Missed reinforcement opportunities, however, were not frequent. Most subjects did not miss more than one per session, often going for complete sessions without a miss, and none exceeded an average of 1.5 per session.

Removal of the limited-hold. When the limited-hold was removed, the experimental conditions duplicated Phase 2, except that the fixed-interval was 63 s instead of 60 s. Most subjects, however, changed their response pattern very little from its limited-hold form. The fixed-interval behavior of a

Fig. 5. Records of Subject 107 on multiple fixed-ratio 50 responses and fixed-interval 60 (or 63) s with an added limited-hold (L.H.). The limited-hold values are given at the end of each record, which shows his last session at that value. The second session shown for limited-hold 1s follows the lengthening of the interval to 63 s. Arrows mark missed reinforcements. Schedule changes are shown by maintained oblique upward and downward pen displacements.

few subjects did become irregular: Total output dropped markedly; response rates fluctuated, even within the same interval; pauses interrupted many fixed-interval runs; and pause lengths varied, sometimes greatly exceeding the interval.

When Phase 3 ended, most subjects had not started to use their watches again. They had learned that instead of clock watching, they could pause a while, then respond in a continuous run through both schedule components, and pause again after the second reinforcement. They could do this with precise regularity while talking, reading a newspaper, or writing daily reports, and most continued to do this with no reduction in reinforcement frequency.

DISCUSSION

The subjects' fixed-ratio performances were, for the most part, predictable from earlier studies with other organisms (e.g., Ferster & Skinner, 1957; Schoenfeld & Cumming, 1960; Sidman & Stebbins, 1954). The

major difference from the research with nonhumans was in the subjects' pattern of responding during the fixed-interval component of the multiple schedule. Their cumulative records did not reproduce the classical picture of pauses followed by gradually accelerated responding as the fixed-interval progressed. Instead, subjects waited nearly as long as or slightly longer than the entire interval, and then they pulled the plunger only once or twice before obtaining a token.

Several investigators, using human subjects, have reported "nonstandard" fixed-interval behavior (e.g., Bentall, Lowe, & Beasty, 1985; Leander, Lippman, & Meyer, 1968; Lippman & Meyer, 1967; Weiner, 1969; Zeiler & Kelley, 1969). These data have led some (e.g., Catania, Matthews, & Shimoff, 1982; Harzem, Lowe, & Bagshaw, 1978; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Lowe, 1979) to inquire into the possible role of verbal behavior in mediating human performance on reinforcement schedules. Others (e.g., Lowe, 1983) went

on, additionally, to conclude that the absence of "typical" fixed-interval scallops in the cumulative record makes the nonhuman model inapplicable to the understanding of human behavior. And yet, when we obtained our data, we felt obliged neither to adduce new explanatory principles nor to discard the nonhuman data with which ours seemed inconsistent. Were we simply not attuned to the significance of these early observations? We think our reasons for considering our findings relatively unremarkable are still convincing, and, in view of the more recent developments, worth sharing.

The subjects' rates and patterns of responding differed in each component of the multiple schedule. Although the fixed-interval pattern was not the classical one, our human subjects' behavior was no less sensitive than that of nonhumans to the reinforcement schedules. Also, when the fixed-interval schedule increased from 30 to 60 seconds, the subjects' pause durations increased accordingly. And when the limited-hold was added, our subjects, like those of Lowe, Harzem, and Bagshaw (1978), decreased their pause durations in the fixed-intervals, and, once having begun, pulled the plunger rapidly until they produced the reinforcer. A missed reinforcement opportunity after having paused too long caused subjects to start pulling the plunger much earlier in the next fixed-interval period. Our human subjects were no less sensitive than nonhumans to changes in the schedule parameters and in the consequences of their behavior.

Yet, clear differences exist between the experimental environment described here and more typical research situations. For one thing, the reinforcers added a meaningful increment to the subjects' weekly pay. These strong reinforcers, more analogous to those typically used in nonhuman than in human studies, perhaps increased the subjects' sensitivity to the contingencies.

Verbal intercommunication, however, not a factor in nonhuman studies, undoubtedly also hastened our subjects' adjustment to procedural changes. It seems both plausible and parsimonious to interpret the later subjects' more rapid adjustment to the contingencies as the outcome of intersubject interaction. As successive individuals first experienced the original reinforcement contingencies,

or the changes in those contingencies, those who entered the booth later came more and more quickly to behave like those who had worked earlier. Subjects who came into the investigation after it had started performed from the beginning in a manner indicating that they had received instructions. It became clear that the subjects' recorded performances were controlled both by the reinforcement schedules and by verbal influences that originated outside the experimental booth.

Nevertheless, the direction in which the social factors exerted their influence was itself determined by the reinforcement schedules. The experimenters did not state any rules to the subjects, nor did they ask the subjects to formulate rules. The formulation and use of rules undoubtedly arose out of past advantages gained from verbal descriptions of contingencies (Skinner, 1969). The communication of rules to others arose from a history of socially mediated reinforcement for such communication, and, it was to be hoped, from current social contingencies inherent in the therapeutic environment that had been established for the ward. The particular instructions the subjects passed to each other were, however, products of the reinforcement schedules, and arose directly from the experimental contingencies. The final performances, then, may be accepted as consequences of the experimental procedures.

Intercommunication among the subjects may be regarded as an early segment of the chain of behavior leading to their performance in the booth itself, and ending with the receipt of the tokens. But the effects of the social interactions were by no means invariant. In spite of the verbal cuing from subjects who underwent the procedures first, many of those who came later did not immediately attain their final performances. Even with shared information and instructions, they had to experience the actual reinforcement contingencies—the final members of the chain—before completing their adjustment.

The efficient fixed-interval performances are partly explained by the subjects' use of watches to time the interval. Although clock watching was not experimentally manipulated or recorded, it was clearly happening. The clock is a discriminative stimulus, produced by observing behavior and, in turn,

controlling subsequent behavior. To the extent that clockwatching—although an interesting and perhaps not completely understood kind of behavior (see, for example, Dinsmoor, 1983)—was responsible for the precise fixed-interval performances, no new principles of verbal control are required to account for the absence of such efficiency in nonhumans. When nonhumans are given a discriminative stimulus that marks the end of each fixed-interval, they behave just as efficiently as humans with clocks.

That humans, even without clocks, can time intervals with greater precision than nonhumans is indeed likely, and worth investigation in its own right. More efficient timing can explain the typical human fixed-interval pattern of one response per reinforcement even in studies that prevent the subjects from using clocks. Temporal control of fixed-interval responding is simply discriminative control, and requires no revision of basic principles.

When we added a limited-hold to the fixed-interval, pauses even a fraction of a second too long caused subjects to miss reinforcement opportunities; they stopped using watches and began pulling the plunger sooner. Their behavioral pattern, still under temporal control, became "break-and-run." But the absence of gradual acceleration of responding within the fixed-interval does not warrant a general rejection of operant principles that have been derived from non-human studies. Had clockwatching itself been under experimental observation, with Holland's (1958) observing technique, for example, this behavior would probably have revealed classical fixed-interval scallops in the cumulative records (Lowe, Harzem, & Bagshaw, 1978).

Lest we be misunderstood, we are in no way criticizing what we believe is an important and fruitful research area—interactions between contingencies and verbal rules in the governance of human behavior. It is, however, one thing to identify verbal control of operant patterning and sensitivity to reinforcement schedules, and another to postulate differences in principle between verbal and other kinds of control. A more complete understanding of verbal behavior may well demand additional principles and changes in existing principles, but to show the necessity for such changes will require more than demonstrations—however ingenious—that the controlling stimuli in a particular

instance are verbal. Some nonhumans, for example, are more sensitive to visual than to olfactory stimuli, and others the opposite. Do these differences require any changes in our conception of the three-term contingency? Similarly, we may ask what it is about verbal control that the three-term contingency does not encompass (Skinner, 1957). The answer will require more than evidence of discriminative control by words, spoken or heard. Indeed, if the study of verbal behavior were to be confined to those instances in which language functions merely as a discriminative stimulus, or as a link in a chain of stimuli and responses, then the role of language would be made to seem trivial.

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