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PARAMETRIC EFFECTS OF REINFORCEMENT FREQUENCY, AMOUNT OF REINFORCEMENT, AND REQUIRED RESPONSE FORCE ON SHELTERED WORKSHOP BEHAVIOR[1]

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Three experiments involving parametric manipulation of reinforcement contingencies were performed with retardates in an automated Sheltered Workshop token economy. Experiment I showed that with amount of reinforcement held constant, work rates were positively related to reinforcement rates on fixed-interval schedules and inversely related to reinforcement rates on fixed-ratio schedules. Experiment II demonstrated an interaction between frequency of ratio reinforcement and torque required to complete a work unit: work rates were positively related to reinforcement rates when required response force was high and negatively related to reinforcement rates when required response force was low. Experiment III revealed that, with reinforcement frequency held constant, there was in inverse relationship between amount of reinforcement and work rate.

The application of the principles of reinforcement schedules to the modification of human behavior requires attention in applied behavior analysis. Unfortunately, the human version of Ferster and Skinner's (1957) *Schedules of reinforcement* does not exist. Existing research on human schedule performance suggests that there are significant differences between human and animal performance. The research of Lindsley (1960) and Sidman (1962) with psychotics, and Barrett and Lindsley (1962), Ellis (1962), Spradlin and Girardeau (1966), and Orlando and Bijou (1960) with retardates has shown that response rates on simple and complex schedules are frequently low, interspersed with long unpredictable pauses. Weiner (1969, 1970) showed that performance of normals is often absent of fixed-interval scallops or fixed ratio post-reinforcement pauses, depending on conditioning history and response cost.

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There is an abundant literature on intermittent reinforcement effects in token economies, *e.g.* (Allyon and Azrin, 1968; Kazdin and Bootzin, 1972). Little research on parametric effects of reinforcement schedules exists, however, possibly due to the many difficulties in obtaining these data in naturalistic settings. Difficulties are often prohibitive as a result of lack of administrative control of the necessary environmental contingencies, *e.g.,* cooperation of institutional staffs, control of drug histories, permission to use appropriate reinforcers.

Yet in practice, the choice of schedule type and value always implies the manipulation of reinforcement parameters. If the principles of scheduling are to be of more than incidental use in applied behavior analysis, research must be done that relates reinforcement parameters found in the laboratory to field situations. The present experiments showed that these principles can be a useful tool to the behavior analyst.

EXPERIMENT I: EFFECT OF FREQUENCY OF REINFORCEMENT

Research on reinforcement schedules with animals (Ferster and Skinner, 1957; Morse, 1966)

has shown that several parameters dealing with the manner in which reinforcements are administered have dramatic effects on behavior outcomes. One of these parameters is the frequency with which reinforcement occurs. In general, it can be said that, with schedules of intermittent reinforcement, *i.e.*, where reinforcement becomes available after a specified time interval (interval schedules), or a specific number of responses (ratio schedules), rate of reinforcement is positively related to response rate (Ferster and Skinner, 1957; Morse, 1966; Catania and Reynolds, 1968; Herrnstein, 1970). The slower the reinforcement rate, therefore, the slower the response rate.

This finding, however, is subject to several qualifications. For instance, a shift from continuous reinforcement to intermittent reinforcement or extinction results in an increase and then a subsequent decline in response rate (Ferster and Skinner, 1957, Chapter 4). Boren (unpublished) also reported an increase in response rate with a decrease in reinforcement rate on fixed-ratio (FR) schedules up to FR 35, after which point a decline in response rate occurred with a decline in reinforcement. Hutchinson and Azrin (1961) reported results similar to those of Boren, using human psychotic patients.

An experiment was, therefore, conducted with Sheltered Workshop employees because of the theoretical and practical importance of the effects of reinforcement frequency on schedule performance. For practical purpose it afforded an easy method for increasing or decreasing a worker's output. Theoretically, we were asking whether reinforcing short chains of responses was more or less effective than reinforcing long chains of behavior when attempting to increase work output.

METHOD

Subjects

Four men and two women, aged 23 to 43 yr (mean = 32) with IQs ranging from 31 to 73 (mean = 47), employed at the Murdoch Center Sheltered Workshop, all had at least 2 yr of experience with token economics and could count to 10.

Apparatus

Schroeder (1972) has described the operation of the Sheltered Workshop. Each employee worked at a workspace with a counter, feedback lights, and tools wired to operant scheduling and recording apparatus. Each tool usage, defined by circuit completion through closure of switches attached to the tools, was recorded as a response. Thus, whenever the programming apparatus set up an occasion for reinforcement, the next tool usage resulted in the flash of a red light to signal a response (tool usage), a green light flash to signal reinforcement, and an advance of the counter. At the end of the 1-hr work period the experimenter gave the subject the number of tokens (poker chips) tallied on his counter. Four types of poker chips served as currency: small white chips equalling 0.1 cent; large white, 1 cent; large red, 5 cents; large blue, 10 cents.

The subject could then spend his tokens at the Workshop store to buy anything from pipe cleaners and toilet articles to small electrical appliances (radios, razors, *etc.*) and catalogue items, *e.g.*, clothing, or he could save his tokens, turn them in for cash at the end of the week for spending at the campus store or on weekend outings.

After the work shift was over, the experimenter recorded total responses (tool usages) per session, total reinforcements (tokens), and work units completed by each employee. Work units were defined as products manufactured, *e.g.*, wires cut, lugs soldered, holes drilled, snaps crimped, *etc.* Since tabulation of work units consisted of counting discrete items completed, interobserver reliability (agreements/disagreements + agreements) was 0.96 or above.

Procedure

All subjects were given six weeks of practice with the apparatus dispensing reinforcement (green light flash and counter tally) non-contin-

gently once per minute to allow for adaptation. During this period, operation of the counter and green light were not correlated with tool usage, but tokens worth one cent were given at the end of a session for each point recorded on the counter.

Subjects were then switched to a contingent reinforcement regime. They were told that they would get tokens only for working and that the counter on their contingency panel would tell them how many tokens they were earning. To make sure they understood, the first session was spent on demonstration. The experimenter went to each employee giving out tokens tallied by the counter, then questioning the employee as to how "the thing" worked. All subjects appeared to understand the system after 15 min of practice. Tokens were then given only at the end of a session.

Each of three subjects participated for ten 1-hr periods per week on each of three fixed-interval schedules (FI 1-min, FI 10-min, FI 60-min). On FI 1-min, reinforcement was delivered for the first response emitted 1 min after the last reinforcement; on FI 10-min, this interreinforcement interval was 10 min; on FI 60-min it was 60 min. Three subjects experienced one week (10 sessions per week) on each of several ratio schedules. For Subject D, every fifth response was reinforced on FR 5, every one hundred and fiftieth response on FR 150, every three hundredth response on FR 300, and every six hundredth response on FR 600. Subject E received one week each of FR 5, FR 50, FR 300. Subject F received one week each of FR 5, FR 50, FR 150, FR 300. Order of schedule presentation was: Subject A, FI 1-min, FI 10-min, FI 60-min; Subject B, FI 60-min, FI 10-min, FI 1- min; Subject C, FI 10-min, FI 1-min, FI 60-min; Subject D, FR 5, FR 150, FR 300, FR 600; Subject E, FR 300, FR 30, FR 5; Subject F, FR 5, FR 50, FR 150, FR 300. Each subject used the same workspace, tools, and job for the duration of the experiment. Subject A soldered lugs to wire tips; Subject B dipped wire tips into a pot of molten solder with a pliers; Subject C cut measured lengths of wire with a pliers; Subject D loosened nuts from Nu-Way studs with a pliers nutdriver; Subject E stripped insulation from wire tips with a wire-stripping pliers; Subject F crimped Nu-Way snaps to wire tips with a crimping pliers.

Since changes in reinforcement rate also result in changes in total amount (money/hour) of reinforcement, this variable was controlled by adjusting the amount of reinforcement to the reinforcement rate. For instance, if reinforcement became available after each minute (FI 1-min), the value of the counter tally was set at 0.1 cent; on the FI 10-min schedule, each reinforcement then yielded 1 cent; and on FI 60-min each counter tally equalled 6 cents. After 10 sessions of performance on one schedule, the subject was simply told: "Okay the counter will work slower (or faster) now; but each count here will be worth X tokens." The standard value of tokens and their exchange rate for money were reiterated. The experimenter also verbalized the contingency whenever paying the tokens at the end of a work period. With ratio schedules, this adjustment procedure was more difficult. To estimate what a subject's rate on FR 5 would be initially, the number of his responses per reinforcement on non-contingent reinforcement schedules was extrapolated and used as an initial value on FR 5. If this estimate was out of line, it was adjusted after 30 min of the first session and the counter tally value was set to yield a total amount per hour comparable to that of the FI schedules. Thus, it was possible to keep total reinforcement amount per session nearly constant across treatments for all subjects.

Results and Discussion

Tool usages and work units per minute on the final day of the six-week non-contingent reinforcement period of adaptation were for each subject respectively: A, 3.1, 0.71; B, 4.5, 0.20; C, 3.6, 0.25; D, 5.0, 0.08; E, 1.7, 0.15; F, 3.1, 0.23.

The mean number of tool usages and work units completed per minute as a function of FI schedule and FR schedule values for contingent

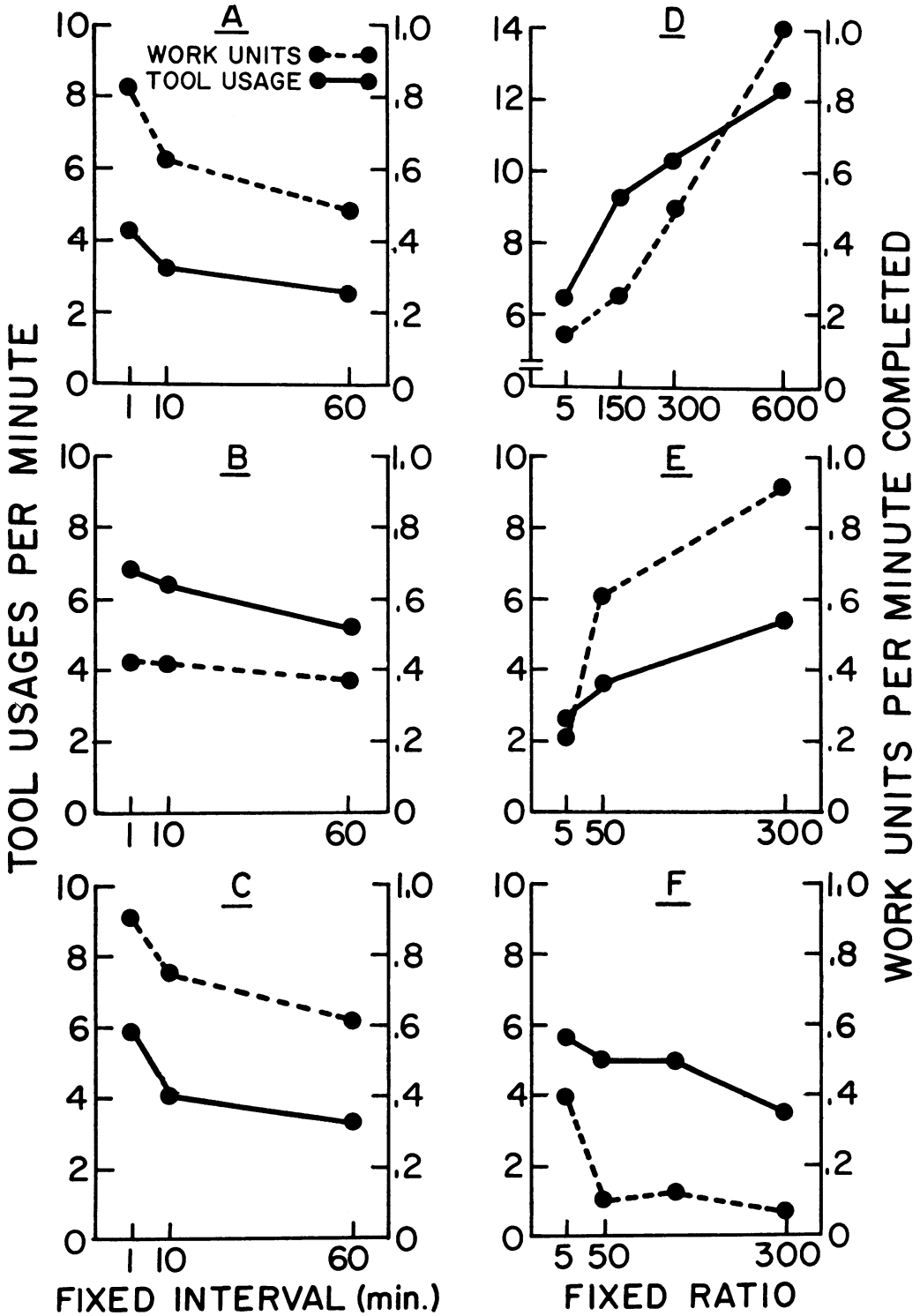

Fig. 1. Mean tool usages and work units per minute as a function of fixed-interval schedule (Subjects A, B, C) and fixed-ratio schedule (Subjects D, E, F). Each point is the average of 10 sessions of performance.

reinforcement are shown in Figure 1. Each point is the mean of 10 sessions of performance. With fixed-interval schedules, an increase in FI value (decrease in reinforcement frequency) was correlated with a substantial decrease in both tool usages and work units completed for all three subjects (A, B, C). The opposite is true for two of the three subjects (D, E) on ratio schedules with an increase in FR value (decrease in reinforcement frequency). Subject F's tool usages and work units, however, decreased with an increase in FR value.

Changes in reinforcement frequency on FI and FR schedules were correlated with marked changes in tool usages and work units completed by all subjects. This effect emerged with different jobs, tools, and reinforcement schedules. Rates of responding were much lower than those ordinarily found in laboratory key-pecking or bar-pressing experiments. This is due to the fact that subjects were using tools to complete work units. This imposed a constraint on tool usage rate because the successful completion of a work unit usually involved an idiosyncratic response topography. For instance, the job of wire cutting involved a chain of responses, *e.g.,* measuring its length on a template, positioning it properly, then cutting it. Only the terminal member of the chain, *i.e.,* cutting, was recorded.

The results found with fixed intervals are similar to those found in animal laboratory research where response rate is positively related to reinforcement frequency in time on interval schedule (see Catania and Reynolds, 1968, pp. 368-370 for discussion). However, in this study no "scalloping" of the response rate between reinforcers was observed.

The increase in response rates with increased FR values found by Boren (unpublished) in animals and Hutchinson and Azrin (1961) in schizophrenics was observed in two subjects (D, E), but over a larger range of FR values. Hutchinson and Azrin (1961) used values up to FR 200, at which point response rates became erratic. Boren (unpublished) noted an increase in response rate up to FR 35 followed by a decrease with higher FR values. Long, Hammack, May, and Campbell (1958) found a decrease in response rate with increases from FR 15 to FR 90 in 4-to-8-yr-old normal children. However, response rates of Subjects D and E in the present experiment were highest at the largest FR values of FR 600 and FR 300 respectively.

The performance of Subject F was opposite that displayed by Subjects D and E, even though all three subjects had jobs involving topographically similar responses (use of pliers). The crimping of snaps by Subject F, however, involved the use of considerably more force per tool usage than either of the jobs done by Subjects D and E.

Notterman and Mintz (1965), in their book on the dynamic properties of responding, noted that, with animals, there was a positive relation between effort expended (grams of force per second) for individual responses and ratio length when the required response effort criterion is low, but not when it is high. Rats pressed a steel ball situated above a calibrated strain guage. Notterman and Mintz found that when effort criterion for a response was low, an increase in fixed ratio was correlated with an increase in the rats' expenditure of effort on each response, but this effect disappeared at higher effort criteria.

This interaction between ratio reinforcement and effort is relevant to skilled performance in the Sheltered Workshop. That is, there may be differences in output on tasks with varying degrees of required response force when different schedules of reinforcement are used. Thus, for Subject F the high force required to crimp snaps may have been a significant factor when the responses required to complete a ratio cycle increased, while the same did not hold for the other subjects (D and E).

EXPERIMENT II: THE INTERACTION OF FIXED-RATIO REINFORCEMENT SCHEDULES AND REQUIRED RESPONSE FORCE

The purpose of this experiment was systematically to vary ratio reinforcement and required re-

sponse force to discover whether the different response patterns of Subjects D, E, and F in Experiment I might be related to required response force.

Method

Subjects and Apparatus

One of the subjects (D) who had been used in the previous experiment served; the apparatus was the same as used before.

Procedure

Subject D was given the job of unscrewing nuts from studs. Before the experiment, the nut on each stud used was tightened with a torque nut-driver such that it required a preset degree of torque to unscrew it: either 1, 2, or 4 in.-lbs. Subject D was then given for four sessions per torque value with FR 5, FR 50, and FR 300 reinforcement schedules. Value of each counterpoint remained constant at 1 cent (one white token).

Results and Discussion

The effect of increasing the ratio required to complete a reinforcement cycle for three levels of torque on tool usage and work units per minute is shown in Figure 2. As can be seen, when the criterion was low (1 in.-lb) response rates were negatively related to reinforcement rates. Just the opposite occurred when the torque criterion was high (4 in.-lb).

It should be noted that Subject D was one of the subjects in Experiment I who showed increased response rates with increases of ratio requirement. Whether the present interaction occurs with subjects who show an inverse relation

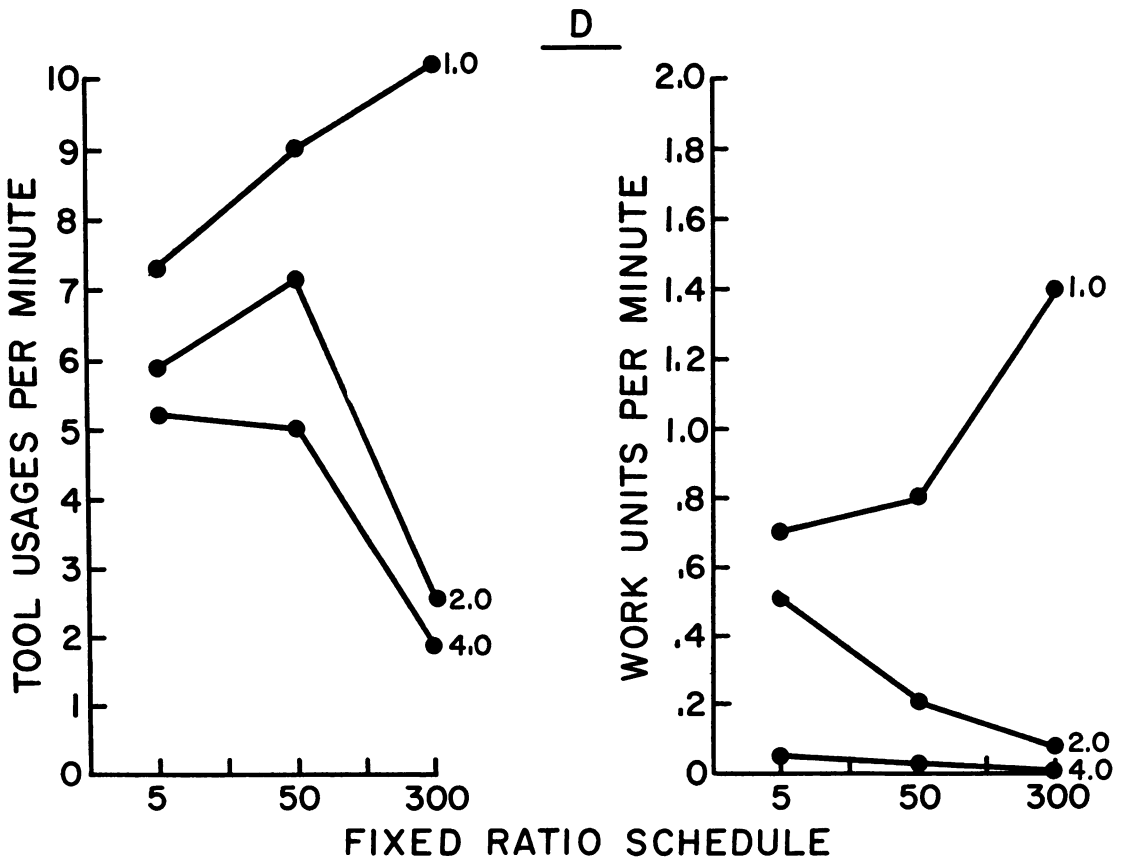

Fig. 2. Mean tool usages and work units per minute for Subject D as a function of fixed-ratio schedule for three values of required response force (1, 2, 4, in.-lb). Each point is the average of four sessions.

between response rate and ratio length should also be investigated. The value of counter points was held constant in this experiment. Response rates dropped so low at the high torque values on FR 300, that twice no fixed-ratio cycle was completed within a session. The drop in output thus may be partially due to extinction because no reinforcers were obtained in these sessions.

The main point to be made, however, is that when required response force is high, a small ratio schedule of reinforcement will maintain output better than a large ratio. If the ratio and torque requirements become too high, the subject will simply quit and perform no work. Presumably, the same effect would eventually occur on FR 5, but the required amount of torque to bring about extinction would be much higher for FR5 than for FR 300.

EXPERIMENT III: EFFECTS OF AMOUNT OF REINFORCEMENT

Another reinforcement parameter of relevance to performance output is amount of reinforcement. A finding in animal and human research is that there is a positive relation between amount of reinforcement and performance (Kimble, 1961, Chapter 6). However, the precise relation between amount of reinforcement and response rate is far from clear, as noted by Morse (1966). For instance, in situations where output is already at a high level, it requires greater amounts of reinforcement to effect an increase in response rate than when initial response rate is low (Guttman, 1953; Hutt, 1954). Keesey and Kling (1961) found that amount of reinforcement was correlated with different response rates only when steady state responding was interrupted. Neuringer (1967) reviewed the inconsistent effects of amount of reinforcement in single response and multiple response situations (*e.g.*, choice of the larger reinforcement). His results suggest that the effects of amount of reinforcement depend partly on whether the subject is shifted from one reinforcement value to another and partly to the extent that a change in response rate influences the amount of reinforcement received.

For rehabilitative purposes, sensitivity to reinforcement amounts is important for the regulation of one's financial affairs in everyday living. It was considered important, therefore, to make an initial attempt at examining the effects of different reinforcement values on the schedule performance of employees. An experiment was done in which amount of reinforcement was varied while reinforcement frequency was constant.

METHOD

Subjects and Apparatus

Four new subjects with the same age and IQ range as those used previously served. The apparatus was the same as in Experiment I.

Procedure

Each subject was given four sessions of each of three reinforcement values: 1-, 5-, and 10-cent tokens. To change the amount of reinforcement, the experimenter simply told each subject that for each count on his counter tally he would receive a white, red, or blue token. Contingencies were explained again each time the subject was paid at the end of a session. Each subject was assigned one of four basic reinforcement schedules, which remained the same throughout the experiment. Subject G was placed on a VI 10-min schedule that yielded reinforcement at various intervals but on the average of once every 10 min. For Subject H, reinforcement became available every 10 min after her last reinforcement (FI 10-min). For Subject I, every fiftieth response was reinforced (FR 50). For Subject J, every seventy-fifth response was reinforced on the average (VR 75). Subject G cut plastic tubing with a pliers; Subject H soldered wires to lugs; Subject I loosened nuts from Nu-Way studs; Subject J crimped snaps.

RESULTS AND DISCUSSION

Figure 3 shows the mean tool usages and work units per minute of each subject as the

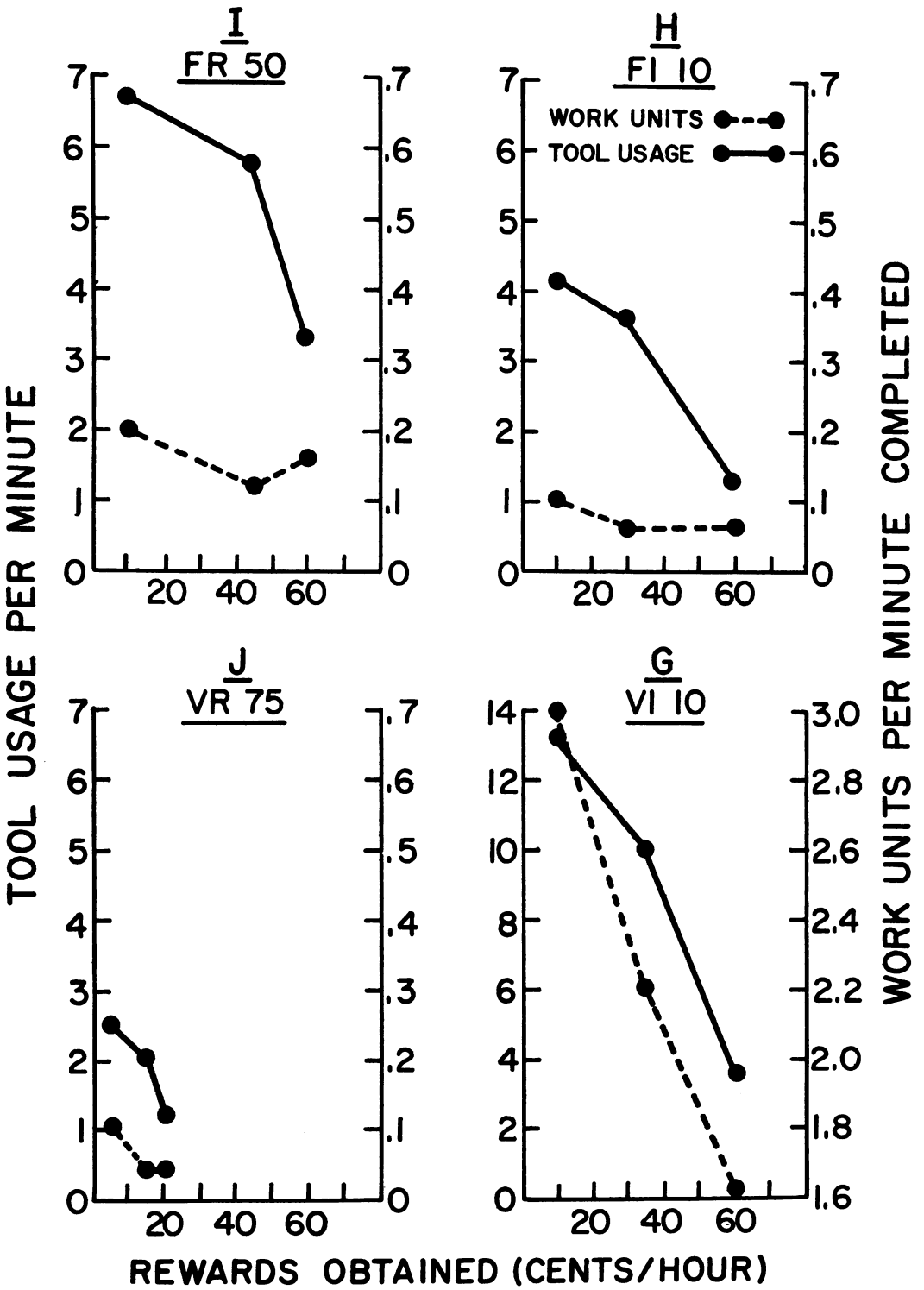

Fig. 3. Mean tool usages and work units per minute for Subjects G, H, I, J as a function of reinforcement amount (cents per hour earned). Reinforcement amount was manipulated by changing the token value from 1 to 5 to 10 cents. Each point is the average of four sessions.

value of counter points increased from 1 to 5 to 10 cents. Cents per hour was calculated as the total monetary value of tokens earned for each session. A large decrease in tool usage occurred with an increase in obtained reinforcement rate for each subject, irrespective of schedule type. A corresponding decrease in work units completed also occurred.

Two possible explanations for the above results come to mind. First, it is possible that the effects obtained are transitional and do not represent stable performance because subjects experienced only four sessions with each treatment. Nonetheless, the fact that four different subjects on four different jobs with four different reinforcement schedules all showed the same effect argues against the view that it was a chance occurrence. Besides, the change in output abruptly followed changes in token value, and usually after only a few reinforcements had been delivered.

It is possible, but unlikely, that since the order of administration of token values for all subjects was 1-, 5-, and 10-cent tokens, some non-experimental variable affected the performance of all subjects systematically. The production schedule of the Sheltered Workshop necessitated termination of the experiment at this point. However, the effect was reproduced repeatedly four months later in all four subjects after one session of experience per token value with similar jobs and reinforcement schedules, and with different orders of treatments.

A second explanation is that the subjects' previous reinforcement history affected their response to different reinforcement amounts. Residents of the institution have little spending money. Salaries in the Sheltered Workshop for the above subjects averaged about 15 cents per hour. Thus, the 30 cents per hour and 60 cents per hour, amounts that subjects on interval schedules gained at the 5- and 10-cent token values, yielded sums that they were not accustomed to managing. Indeed, the two subjects on ratio schedules could have earned up to $16.00 per hour if they had high tool usage rates at the 10-cent token value, rates they had demonstrated on other occasions.

All of the present subjects had worked in the Sheltered Workshop for two or more years and had well established work habits. The earning of large sums of money had never been part of their experience either within or outside the institution. Thus, when token value increased, instead of increasing their output, they adjusted their work rates downward so as to approximate total earnings they had been used to making. It should be noted, however, that work rates did not markedly change within each session as high numbers of counter points cumulated.

Another possible explanation of the present results is that subjects did not choose to earn more money because they had no place to spend it. This explanation is highly improbable. All subjects both before and after the increase in amount of reinforcement earned much less money per week than they could have spent on individual items at the Workshop store or the campus store, *e.g.,* radios, clothing, *etc.*

GENERAL DISCUSSION

It would be premature to try to specify all the possible implications of parametric manipulation of reinforcement for applied behavior analysis. Only a few examples will be given.

Experiments I and II suggest that, as the shift in external reinforcers to more intermittent schedules is made, the use of ratio rather than interval schedules might be more effective in maintaining behavior when the required effort per response is low. The average frequency of reinforcement on interval schedules usually approaches the frequency programmed by the experimenter. A change in value of the interval schedule changes the interresponse time distribution, but the reinforcements per opportunity remain constant. With ratio schedules, however, average frequency of reinforcement depends on the average interresponse time which, in turn, is determined by rate of responding by the subject. The subject can, therefore, increase reinforce-

ment rate even though the value of the ratio is increased.

The results of Experiment II suggest that caution should be exercised in controlling for effort when reinforcement frequency is changed. If a task is too effortful, a decrease in reinforcement frequency may potentiate a decrease in performance, rather than increase the desired behavior. In Experiment II, for instance, it was found that, for a response with a low force criterion, an increase in fixed-ratio requirement was correlated with an increase in response rate. With a high force criterion, an increase in the ratio requirement had the opposite effect, *i.e.*, a decrease in response rate occurred.

Finally, the results of Experiments I and III suggest that the effects of frequency and amount should be considered when values of intermittent reinforcement schedules are manipulated. As Morse (1966) noted, the lack of close correlation of amount of reinforcement with response rate "has fostered the tendency to regard reinforcement as a constant effect with magnitudes below some threshold value not being reinforcers, and with magnitudes above that value being equally effective reinforcers." Experiment I showed that, with amount held constant, a change in reinforcement frequency had different effects on interval and ratio schedules. Experiment III showed that, with frequency held constant, increasing the amount of reinforcement had similar effects on both interval and ratio schedules. Therefore, the combined effects of frequency and amount are likely to bear a complex relation to performance on intermittent reinforcement schedules and should be specified in future research when possible. The results of the third experiment also suggest that the effects of amount of reinforcement may be rather specific to a situation and its reinforcement history.

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