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SOME EFFECTS OF RESPONSE COST UPON HUMAN OPERANT BEHAVIOR

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Three experiments are reported which investigated the effects of cost (point loss per response) upon human-observer responses maintained by VI and FI schedules of reinforcement (acquisition of points *via* critical-signal detections). (I) Cost attenuated VI response rates without substantially disturbing the constancy of responding, regardless of the presentation sequence of the no-cost and cost conditions. (II) FI scalloping appeared only under cost conditions. Under no cost, a constant rate of responding (similar to VI performance) characterized inter-reinforcement intervals. Exposure to cost did not prevent the recovery of previously established no-cost baselines. (III) FI irregularities, analogous to those commonly observed under FI reinforcement schedules, may be produced by different temporal presentations of the no-cost and cost conditions.

The results of all three experiments emphasize the importance of cost as a factor in the maintenance of human behavior on schedules of positive reinforcement.

The human organism seldom produces positive reinforcement without some response "cost"(*e.g.*, physical, monetary). Relatively few studies of operant behavior, however, have systematically investigated response cost as a determinant of the human organism's adjustment to the contingencies of positive reinforcement.

The purpose of the experiments reported here was to assess the effects of response-produced cost (point loss per response) upon human operant behavior maintained by VI and FI schedules of positive reinforcement (acquisition of points *via* critical-signal detections). The concurrent reinforcers chosen can be quantified precisely along qualitatively comparable reinforcement dimensions, and are particularly germane to the human situation.

EXPERIMENT I: RESPONSE COST AND VI PERFORMANCE

This experiment was concerned with the effects of concurrent schedules of response cost and VI reinforcement upon human observer responses. Holland (1958) has shown that relatively constant inter-reinforcement rates of observer responses are emitted when critical signals (reinforcements) are programed on VI schedules. The frequency of observer responses was found to decrease as signal rate decreased. Unlike Holland's study, the present data were obtained when observer responses were emitted under two conditions of schedule information and under explicitly programed response-cost contingencies in which reinforcement was not only signal detections but also concomitant 100-point rewards per detection.

Method

Subjects. The subjects were four male humans, aged 18-21 who were paid $1.25 per hour for their services.

Apparatus and Task. The *Ss* sat alone in an experimental cubicle facing a display which consisted of a series of 40 lamp baffles arranged in three concentric circles behind a frosted-glass screen. Each baffle contained a red light bulb. Switching circuitry was used to program presentation schedules of red (critical) signals and to randomize their spatial location on the frosted-glass screen.

The *Ss*' 1-hr task was to monitor the display for red signals. The red signals were non-transient, *i.e.*, they remained available until detected. Observation of the display was made contingent upon the pressing of an observa-

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tion lever (with a force of 20 g through a distance of 1 cm). By pressing this lever (observer response), the *Ss* could observe the display for only 0.3 sec, even when the lever was held down. Thus, each successive "look" at the display required the release and redepression of the observation lever.

If scheduled, a red signal would appear on the display (0.3-sec duration) after a single observer response. If no red signal was scheduled, the display remained blank after an observer response.

When a red signal was detected, the *Ss* were required to "report" it by pressing another lever. A reinforcement bell sounded; and a Veeder-Root digital counter, mounted in front of the *Ss*, registered 100 points each time a red signal was detected and reported correctly. This 100-point reinforcement provided feedback to the *Ss* on the day-to-day quality of their performance.

Observer responses were recorded continuously on a Gerbrands cumulative recorder.

Procedure. The observer responses of each *S* were conditioned separately (1-hr sessions daily) under a 1-min variable-interval (VI 1), a 3-min variable-interval (VI 3) and a 9-min variable-interval (VI 9) presentation schedule of red signals, in that order. Subjects S15 and S12 were conditioned with schedule information under no-cost and cost conditions, respectively. Subjects S34 and S48 were conditioned without schedule information under no cost and cost, respectively. Under the no-cost condition, the observer responses of the *Ss* were emitted without loss of points (cost/payoff = 0/100). In the cost condition, the counter subtracted one point from the *S's* score for each observer response (cost/payoff = 1/100).

For all *Ss*, each of the VI schedules was associated with a different stimulus light. The no-cost and cost conditions were also associated with different environmental stimuli. A white bulb was lit during the cost condition, and it was extinguished during the no-cost condition.

After 3 hr of conditioning on each of the three VI schedules, the schedules were presented as a three-component multiple schedule under either no-cost or cost conditions. The components of this schedule for both no cost and cost were presented in a fixed order: a 20-min VI 1 schedule presented in the presence of a yellow light; a 20-min VI 3 schedule presented in the presence of a green light; a 20-min VI 9 schedule presented in the presence of a blue light. The *Ss* were exposed to three cycles (*i.e.*, three daily sessions) of this multiple schedule.

The three-component multiple schedule was then subdivided into a six-component multiple schedule by introducing either a 10-min cost or a 10-min no-cost period, under the control of the on-off white light, during each 20-min component. The *Ss* initially conditioned under the no-cost condition were exposed to the cost condition and vice versa. The components of the six-component schedule for the *Ss* initially conditioned under no cost were presented in a fixed order: a 10-min, no-cost VI 1 schedule; a 10-min cost VI 1 schedule; a 10-min no-cost VI 3 schedule; a 10-min cost VI 3 schedule; a 10-min, no-cost VI 9 schedule; a 10-min cost VI 9 schedule. The presentation order of components for the *Ss* initially conditioned under cost was also fixed and was identical except that the presentation order of no cost and cost for each schedule was reversed.

The *Ss* were conditioned for 3 hr on the six-component multiple schedule. The colored lights of the three-component multiple schedule were associated with the same VI schedules under the six-component multiple schedule. The on-off white light and the auditory-visual cues produced by the action of the counter provided information on the differential cost-to-payoff contingencies.

Instructions. At the beginning of the first hour of the conditioning (under the VI 1 schedule), instructions were read to the two subjects (S15 and S12) given schedule information:

> "This is a vigilance task. Your job it to detect red signals that will appear on the screen every once in awhile. You will not be able to see these signals unless you press and release this lever (indicating the observation lever). Holding down this lever will not enable you to see the scope continuously. Each time you wish to take a look at the scope to search for red signals, you must re-press this lever and re-release it. When you detect a red signal, report it as rapidly as you can by pressing this other lever (indicating the report lever) and then

releasing it. Press the report lever only *after* you detect a red signal. Each time you correctly detect and report a red signal, a bell will ring and the counter, which is placed before you, will register 100 points. This is your reward for each red-signal detection. Your task for the next hour is to detect as many red signals, that is, score as many points, as possible.

You will notice that there are three differently colored light bulbs mounted on the wall. Throughout this session, the yellow light will be lit. Whenever the yellow light is on, it means that the red signals will appear 60 times during the session. Their occurrence, however, will be unpredictable; that is, two successive red signals can appear anywhere from less than a second apart to as long as 2 min apart. On the average, however, a red signal will appear once a minute or 60 times during the next hour."

Additional brief instructions were given to the "schedule information" subjects before their first exposure to the VI 3 and VI 9 schedules. As in the instructions for the VI 1 schedule, they were informed that the red signals would appear unpredictably, either on the average of once in 3 min (for the VI 3 schedule) or once in 9 min (for the VI 9 schedule). They were also told that for both the VI 3 and VI 9 schedules, the inter-signal range was less than a second to twice their respective mean inter-signal interval. They were given no other instructions.

The two *S*s who did not receive schedule information were given only the first paragraph of the instructions above.

Results and Discussion

Figures 1 and 2 present the response rates during the third hour of conditioning under the six-component multiple schedules. Figure 1 shows the effects of cost upon VI 1, VI 3, and VI 9 performance, with and without schedule information, previously maintained under no-cost conditions. In Fig. 2, response rates were conditioned, with and without schedule information, under cost before the introduction of the no-cost condition.

Inspection of these figures reveals that for each VI component, with and without schedule information, cost-response rates were lower than their respective no-cost rates. The response suppression produced by cost did not markedly disrupt the constancy of responding between reinforcements which characterized no-cost performance. These effects are analogous to those occurring when response-produced shock punishment is added to the food-rewarded VI performance of pigeons (Azrin, 1960). Unlike Azrin's data, however, no evidence could be found in the present data to suggest any recovery from the effects of cost, either within or between experimental sessions. Furthermore, the reintroduction of the no-cost condition did not produce any transitory enhancement of previously established cost baselines.

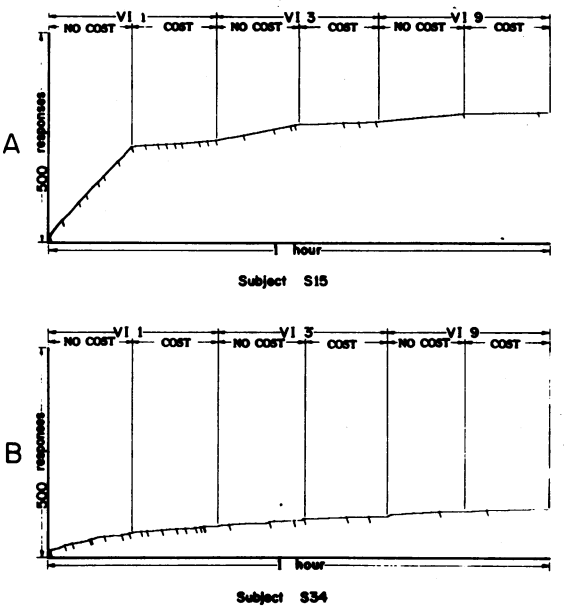

Fig. 1. Effects of cost, either with schedule information (S15) or without schedule information (S34), upon several variable-interval performances conditioned under no cost. Vertical marks on the cumulative-response curve indicate the occurrence of 100-point rewards.

With or without schedule information, no-cost and cost response rates decreased (except for the VI 9 component under cost in Fig. 1B) as the rate of VI reinforcement decreased, regardless of the conditioning sequence of no cost and cost. Holland (1958) had previously demonstrated this relationship under no-cost conditions.

The response rates on the VI schedules which had been conditioned separately, under either no cost or cost, were maintained under the three-component multiple schedule. This

was not true for the six-component multiple schedule. The introduction of a 10-min cost period within each no-cost VI component (Fig. 1) consistently reduced the no-cost response rates of the three-component multiple schedule. The introduction of a 10-min no-cost period within each cost VI component (Fig. 2) slightly increased (except for the VI 1 component under cost in Fig. 2B) the cost response rates previously established in the three-component schedule.

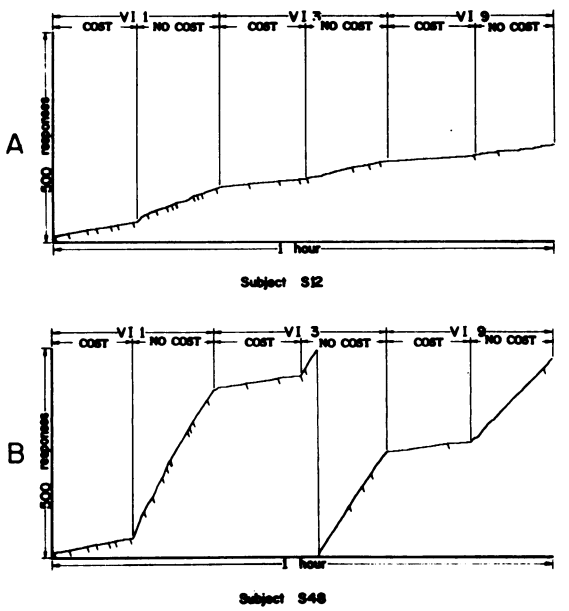

Fig. 2. Effects of no cost, either with schedule information (S12) or without schedule information (S48), upon several variable-interval performances conditioned under cost. Vertical marks on the cumulative-response curve indicate the occurrence of 100-point rewards.

EXPERIMENT II: RESPONSE COST AND "TYPICAL" FI PERFORMANCE

In a recent study, Azrin (1958, p. 184) reported that when human *Ss* were required to exert little physical effort (*i.e.*, 15 g of force through a distance of approximately 2 mm) in order to emit an observing (button-pressing) operant, ". . . the rate of response usually was maintained at several responses per second with little or no scallops during prolonged exposure to a fixed-interval schedule of reinforcement." When a heavier button was substituted, reduced response rates and typical FI scalloping characterized performance, even in the early phases of training. Skinner and Morse (1958) have noted the same general finding in a study of wheel-running behavior of rats under FI reinforcement. Deceleration in running before reinforcement (*i.e.*, S-shaped inter-reinforcement curves) was removed (producing typical FI scalloping) when wheel friction was increased.

The purpose of the present experiment was a further analysis of response cost as a factor determining the emission of "typical" FI performance.

Method

Subjects. The subjects were four male humans, aged 17-21, who were paid $1.25 per hour for their services.

Apparatus and Task. The same apparatus and task were used as in Experiment I.

Procedure. The observer responses of the *Ss* were conditioned without cost for an hour daily under an FI 1 presentation schedule of red signals (and 100-point rewards per detection) until their response rates stabilized. Following stabilization of response rates under no-cost conditions, two 30-min periods of cost were introduced, involving a loss of 1 point per response. This was followed by the reintroduction of the no-cost condition for a 30-min period.

A yellow light remained lit during each experimental session. This light provided a discriminative stimulus (S^D) for the *Ss*, *i.e.*, responses were reinforced only in its presence. In addition, the yellow light indicated that the presentation of red signals had not been changed either within a session or from session to session. Pretrials indicated that some *Ss* appeared to suspect the change in the schedule of reinforcement, so that they emitted erratic exploratory behavior. Because rapid response stabilization was desired, the yellow light was added to suggest to the *Ss* that comparable conditions prevailed from day to day.

The no-cost and cost conditions were associated with the same S^Ds (*i.e.*, the on-off white light) as in Experiment I. These associations were maintained throughout the experiment to provide the *Ss* with information on cost contingencies.

Instructions. All subjects received the same instructions as the no-schedule information subjects (S34 and S48) in Experiment I.

Results and Discussion

All *Ss* exhibited a reasonably stable FI 1 performance under no-cost conditions by the end of the fifteenth hour of conditioning. Table 1 reveals the negligible difference between the average no-cost response rates emitted by two of the four *Ss* during Sessions 12-15. Comparable differences in response rates during these sessions were obtained from the other two *Ss*. A constant inter-reinforcement rate of responding characterized the performances of all *Ss* during these sessions.

Table 1
Average No-cost Response Rates in Responses per Minute Before the Introduction of Cost

Conditioning Session	*S 10*	*S 45*
12	229.8	60.9
13	219.3	60.0
14	215.0	59.3
15	233.7	58.5

Figures 3 and 4 show the effects of cost upon FI 1 performance conditioned under no cost. These figures present cumulative-response curves for two of the four *Ss* tested under both no cost and cost during the sixteenth and seventeenth hours of conditioning. The two other *Ss* that were tested showed similar effects.

Inspection of Fig. 3 and 4 reveals that for all *Ss* the no-cost response rates and response patterns were similar to their respective rates and patterns during Sessions 12-15. Without cost, observer responses did not exhibit scalloping between reinforcements. The constancy of responding between reinforcements resembled variable-interval (VI) performance, not FI performance.

The introduction of the cost contingency midway through the sixteenth hour of conditioning markedly reduced response rates and produced fairly immediate flat scalloping between reinforcements. The magnitude of the cost effects appeared somewhat unrelated to no-cost baselines of responding. Exposure to cost produced scalloping and extremely low response rates regardless of established no-cost baselines.

Response rates under cost during the seventeenth hour of conditioning (Fig. 3B and 4B) were similar in general to cost response

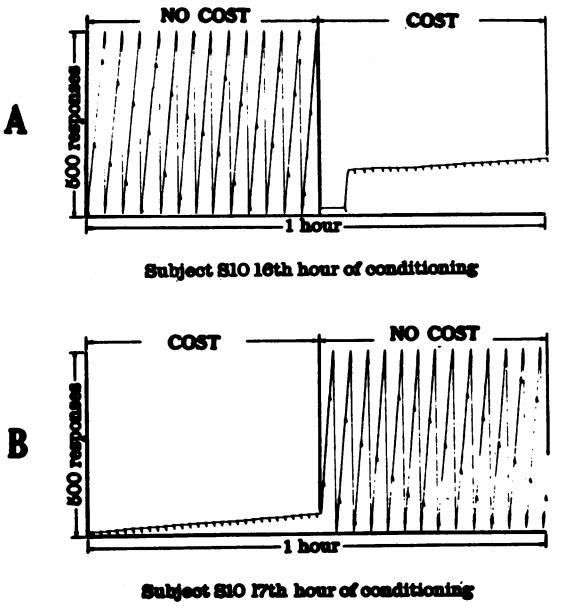

Fig. 3. Cumulative-response records of S10 showing the effects of no cost and cost upon instrumental observer responses conditioned by an FI 1 schedule of reinforcement. Vertical marks on the cumulative-response curve indicate the occurrence of 100-point rewards.

rates during the sixteenth hour of conditioning. Low response rates and flat scalloping again characterized performance. The rein-

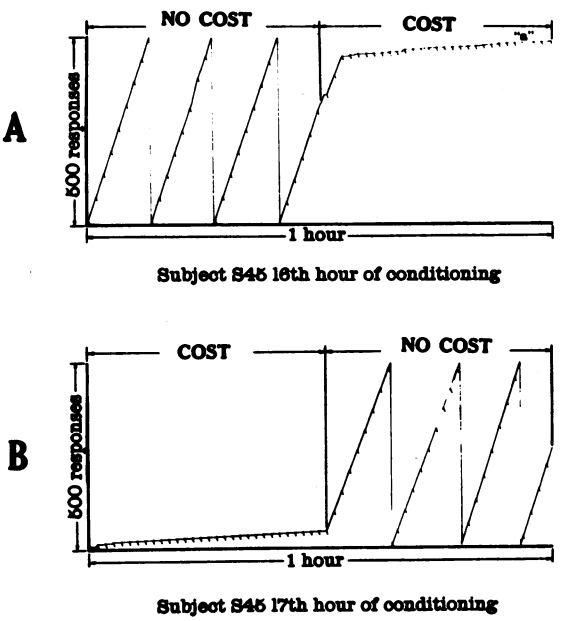

Fig. 4. Cumulative-response records of S45 showing the effects of no cost and cost upon instrumental observer responses conditioned by an FI 1 schedule of reinforcement. Vertical marks on the cumulative-response curve indicate the occurrence of 100-point rewards.

troduction of the no-cost condition during the seventeenth hour of conditioning rapidly increased response rates for all *Ss* to their respective sixteenth-hour no-cost levels and removed the flat scalloping patterns emitted under the cost condition. Apparently, exposure to cost did not produce a permanent modification in no-cost response rates and response patterns.

Differences in response cost may possibly account for some of the inconsistency between the findings of Holland (1957, 1958) and Blair (1958). Studies by Holland demonstrated that the mere detection of critical signals by human observers can be used as a positive reinforcer for instrumental observer responses. The FI presentation schedules of critical signals produced observer-response scallops characteristic of the FI lever-pressing and key-pecking performances of infrahuman organisms controlled by food reinforcement.

Holland's results demonstrate: (a) the consistency of response patterns within and among human *Ss* under FI reinforcement schedules, and (b) the remarkable similarity in the behavior emitted by human and infrahuman organisms when both are exposed to FI reinforcement contingencies. However, the results of experiments by Blair indicate that this behavior shows wide individual differences. In a similar task and under similar FI schedules, Blair's subjects did not always show FI scalloping.

In the Blair experiments, a light source was attached to the subject's head. Critical signals could be seen only when the subject's head was properly positioned for direct scanning of the display (observer response). On the other hand, the observer responses in the Holland studies involved both appropriate positioning of the head (like Blair's observer response) *and* the pressing of a key. This additional observer-response component may have increased the "physical cost" of responding and may have contributed to the development of FI scalloping. This hypothesis is consistent with the findings of Azrin (1958) discussed previously.

EXPERIMENT III: RESPONSE-COST CONTINGENCIES AND "DEVIANT" FI PERFORMANCE

In Experiment II, FI scalloping was contingent upon the existence of response cost. The present experiment attempted to demonstrate that several different types of FI response patterns may be produced by a judicious scheduling of the no-cost and cost conditions.

Method

Two of the *Ss* tested in Experiment II were given additional FI 1 conditioning sessions under different presentation sequences of the no-cost and cost conditions in order: alternating inter-reinforcement intervals (1-min) of no cost and cost; alternating 30-sec periods of cost and no cost between reinforcements in which the cost condition always followed reinforcement; alternating 30-sec periods of no cost and cost between reinforcements in which the no-cost condition always followed reinforcement; alternating 15-sec periods of no cost and cost between reinforcements in which the no-cost condition always followed reinforcement; alternating 15-sec periods of cost and no cost between reinforcements in which the cost condition always followed reinforcement.

After 2 hr of FI 1 conditioning on *each* of these five response-cost schedules, the schedules were presented as a seven-component multiple schedule (Ferster & Skinner, 1957). Each of the five response-cost schedules was presented for 10 min (in the same fixed order as the individual conditioning sessions), following a 10-min no-cost period and a 10-min cost period within a single experimental session. Performances under all response-cost schedules were maintained by concurrent FI 1 positive reinforcements (critical-signal detections and 100-point rewards per detection). As in Experiment I and Experiment II, a lit white bulb was associated with the cost condition. The no-cost condition was in effect when the white light was off. The *Ss* were exposed to two cycles (*i.e.*, two daily 70-min sessions) of the seven-component multiple schedule.

Results and Discussion

Figure 5 presents the second-cycle performance under the seven-component multiple schedule for one of the *Ss* (S45) tested. Similar effects were obtained from the second *S*. Examples analogous to many of the commonly observed FI irregularities can be found within and among the various components of the

multiple schedule. Subject S45's previously established (Experiment II) FI 1 performances under no-cost and cost conditions were replicated (components 1 and 2 in this record), even when cost contingencies were changed after each reinforcement (component 3).

The constancy of responding between reinforcements under the no-cost condition (component 1) represented a failure of S45 to respond to the fixed temporal aspects of FI reinforcement. This pattern of responding has been commonly observed under VI schedules of reinforcement, in which the occurrence of individual reinforcements is unpredictable. On the other hand, S45's cost performance (component 2) was a maximally efficient adjustment to the FI 1 pattern of reinforcement. Positive reinforcements were procured with minimum response expenditure, indicating highly accurate temporal discriminations of the inter-reinforcement interval.

The flat scalloping which characterized cost performance is similar to highly efficient DRL performance. In a DRL schedule, the organism is required to space his responses temporally in order to obtain positive reinforcements. As here, there is a "cost" (loss of positive reinforcement) in responding inappropriately to the temporal contingencies of positive reinforcement under a DRL schedule.

As in the no-cost response pattern, the flat scalloping emitted under cost may be considered an FI irregularity when compared to the deep scalloping usually obtained from infrahuman organisms. Such deep scalloping has been effected in component 4, by programing alternately the cost and no-cost conditions, in that order, every 30 sec.

The record shows instances of single and multiple bites or runs (components 4 and 7), single and multiple knees (components 5 and 6), double scallops (*e.g.*, at "a" between components 3 and 4), and "running through" reinforcements (*e.g.*, at "b" between components 4 and 5). Although triple scallops are not produced in this record, they might have rather easily been effected by varying the sequence of no-cost and cost conditions. Negative accelerations (failures to sustain the terminal rate) also do not appear in the record, but could probably have been produced by introducing intermittent cost between the no-cost and cost sequence within a single inter-reinforcement interval.

There appears to be little question that characteristics of FI performance may be contingent upon response cost. Whether or not specific instances of irregular (either intrasubject or intersubject) FI patterns in fact develop as a function of response-cost con-

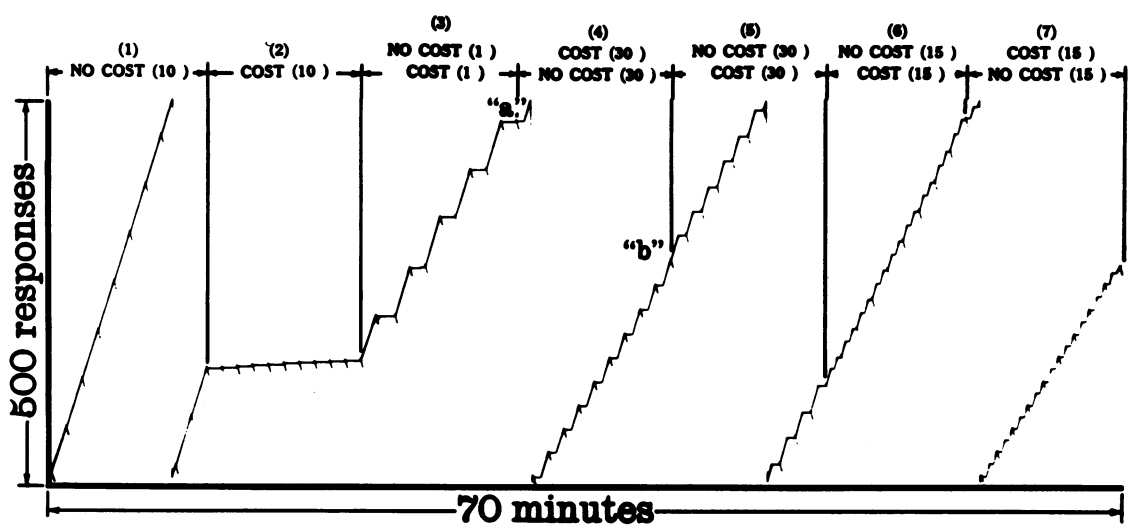

Fig. 5. Deviant FI 1 performance in a seven-component multiple schedule produced by different presentation sequences of the no-cost and cost conditions. The temporal presentation schedules of the no-cost and cost conditions are indicated in the parentheses to the right of each condition. The components of the multiple schedule are numbered in the parentheses above the response-cost contingencies and their associated presentation schedules. Vertical marks on the cumulative-response curve indicate the occurrence of 100-point rewards.

tingencies is problematical. The important point is that response cost must be attended to (even when not explicitly programed) as a possible determinant of operant behavior. Attempts to account for FI responding in terms of only the contingencies of positive reinforcement are parsimonious, but they may be inadequate to provide a complete specification of the controlling factors.

REFERENCES

Azrin, N. H. Some effects of noise on human behavior. *J. exp. Anal. Behav.*, 1958, **1**, 183-200.

Azrin, N. H. Effects of punishment intensity during variable-interval reinforcement. *J. exp. Anal. Behav.*, 1960, **3**, 123-142.

Blair, W. C. Measurement of observing in human monitoring. *Science*, 1958, **128**, 255-256.

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

Holland, J. G. Technique for behavioral analysis for human observing. *Science*, 1957, **125**, 348-350.

Holland, J. G. Human vigilance. *Science*, 1958, **128**, 61-63.

Skinner, B. F., and Morse, W. H. Fixed-interval reinforcement of running in a wheel. *J. exp. Anal. Behav.*, 1958, **1**, 371-379.

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